Fear and Flames – An investigation into the landscape level affordances of the Wildfire Package and their impact on modern human attitudes to fire and related landscapes of fear

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Accepted in December 2017

Dissertation submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor of Philosophy

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Abstract

Fire is an important aspect of human culture with a relatively unknown deep evolutionary history whose origins are a subject of interest for research. In this thesis it is argued that the desire to feel safe and minimise risks to a large degree determines the habitat use choices of primates. This research project approaches early hominin fire-use in an innovative way by focussing on the adaptive selective benefits of intelligent palaeoenvironmental risk management strategies and subsequent reductions to vigilance investments and stress levels. It has isolated the point that almost no work had been carried out on the testing of modern human attitudes towards fire. On the basis of field studies carried out in the UK and in Uganda using questionnaire surveys, a major new line of evidence concerning modern human attitudes to fire is presented that may be useful to the testing of early fire theories. The research has made contributions to three main areas in coming to its conclusions: the principal contribution is the first systematic cross-cultural (and cross-continental) study into the attitudes and framing of fire; with one study cohort made up of Ugandan Batwa. The results identified a strong cross-cultural awareness of the usefulness of fire and the clear correlation between a broad history of fire-use and a positive framing of fire. The second major contribution to the study of the origins of hominin fire-use is the 'Wildfire Package' concept; a novel way of viewing the very variable landscape affordances of wildfire. The third contribution is the idea of 'Fear and Flames'; a new early hominin fire-use hypothesis grounded in Landscape of Fear theory.

Acknowledgments

Many people have helped me in this project and are deserving of my gratitude and thanks. John Gowlett, who single-handedly supervised the vast majority of this project, has provided excellent guidance and skilfully reined in my occasional forays into areas I shouldn't have gone. It is clear to me that without John's patience and serenity this dissertation would never have been finished. Mark Bellis has intermittently provided comments and critique that have had massive bearing on the direction of this study; for his input I will be forever grateful. A big thank-you is due to James Brink and colleagues at the National Museum (Bloemfontein) for his help and support during the South African research. Thanks to Robin Crompton for help in the early part of this study. Thanks must also go to Maryjka Blaszczyk for her generous permission to use her Soetdoring photos.

A huge debt of gratitude is due to my good and long-time friends and colleagues Miha Logar and Niwagaba Christopher in Kabale (Uganda) for preparing so effectively for my arrival and for making my research so successful and smooth (and so much fun). Extra special thanks have to go to Miha Logar for: organising my gorilla interactions; helping organise the Rutwa translations; letting me be John Torode for a day I will never forget; and also for providing me with a 'home-base' at Lake Bunyonyi to recuperate after fieldwork and do my data inputting. Perhaps an even greater debt of thanks is owed to Niwagaba Christopher for putting his life on hold for six week, for letting me name his daughter and for the use of his family home as a research base when in Kashasha sub-county. The Batwa data could never have been collected were it not for the help of my close Batwa friend Ssemiseru Wilbur. His smile and charm were as invaluable as his excellent English and commitment to translational accuracy. A big thank-you is also due to Jimmy *'I know absolutely everyone'* Brown who was not only invaluable in collecting the NBA data but also single-handedly disproved

‘Dunbar’s number’ by knowing absolutely EVERYONE in South-West Uganda. Massive thanks must go to Charlotte Bigland for her friendship and support throughout this study. Charlotte always has a positive perspective and was expert at making me feel good about myself and showing me how fortunate and skilled I am; her positive outlook on life and all-encompassing love of cake is truly inspirational. Further thanks are due to Matt Grove for statistical advice, to Kris D’aout for joining me for combined Mersey kayaking and academic support adventures, and the ‘Room 1.06 Posse’ for their intense grammatical discussions, emotional support and friendship during my write-up.

Finally I owe everything to my family for their support and encouragement in seeing this project through to conclusion. To Brooser Caris for helping me to crystalise what I want from life; you will NEVER be forgotten. To Anya Rose Caris for being the loveliest thing that has ever happened to anyone ever; a constant source of joy and support. To my parents and siblings for their emotional support, and for eventually stopping asking me ‘*so exactly when are you going to actually finish?*’. However the biggest thanks has to go to Karen Hughes for being the love of my life, for kicking my rump when it was needed, and for providing the emotional support and the hard-headed advice that was needed to bring this project to fruition. It could not have been completed without you; many, many, many thanks.

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Chapter 1

Theoretical aims

i) To investigate where the weaknesses are in the current paradigms that exist around the onset of hominin fire-use, and to address whether a clear picture of ancestral behaviour can be envisioned without a re-evaluation of current paradigms?

ii) To generate a model that: i) mitigates the weaknesses of existing models or ideas regarding the nature of the onset of hominin fire-use; ii) takes into account the potentially adaptive selective requirements of effectively managing risks and reducing stress; and iii) clearly models the adaptive selective forces plausibly capable of generating patterns that researchers have (archaeologically, morphologically and psychologically) identified.

iii) To assess if adaptive-selective pay-offs created by adaptations within mental landscapes linked to Wildfire Package affordances can provide a robust driver for the initial uptake of hominin fire-use?

Fieldwork goals

i) To enlarge with new evidence the existing body of knowledge of human attitudes to fire and distinguish if evidence of ancestral behavioural relics can be identified within the fire-related mental landscapes of modern populations.

ii) To identify and document how fire fits into current human mental landscapes of fear and to identify if this differs between cultures.

iii) To cross-culturally test for determinates of modern fire-based landscapes of fear.

iv) To test if the Fear and Flames Hypothesis (constructed as part of this study) is consistent with, and discernible in, aspects of the attitudes to fire of modern populations.

Introduction

Fire has been a key feature of terrestrial life in many diverse ecosystems for millions of years (Pausas and Keeley 2009, Cochrane and Ryan 2009, Belcher 2016) and is a well-recognised adaptive selective evolutionary driver (e.g. Darwin 1871, Burton 2009, Attwell et al. 2015, Miao et al. 2016). Fire-use has niche constructive effects, altering selective environments for genetic and cultural evolution (Attwell et al. 2015). The 'initial onset of anthropogenic fire-use' has been observed to be a critical point in human history (Darwin 1871, Burton 2009, Berna et al. 2012, Gowlett 2016) and is hypothesised to correlate with an increase in brain size (Miao et al. 2016) intellectual complexity and sophisticated cognitive abilities (Pruetz and LaDuke 2010, Twomey 2011) as well as activity levels and range size (Leonard and Robertson 1992). Even Darwin's observation was not original; the acquisition of fire by humans plays a major role in the creation mythologies and cosmologies of a number of ancient historical as well as pre-historical cultures (e.g. Prometheus is responsible for stealing fire from the gods in Ancient Greek mythology) (Goudsblom 1986). Lovejoy (1981) proposed that *Homo* autopomorphies (e.g. encephalisation) were unlikely to arise *de novo* from elemental behaviours seen in other hominids, and that something new and different is required; here late Pliocene and/or early Pleistocene ancient hominin fire-use is suggested.

However, the nature of the pathway and the exact timing of the initial incorporation of fire into hominin technological and behavioural toolkits remain controversial; investigation of this issue provides the focal point of this study. This thesis provides new ideas and new data to approach these issues. New ideas include a new way of looking at the affordances of wildfire, termed the Wildfire Package (which it is hoped will gain traction amongst researchers), and also a new model, ‘Fear and Flames’, that outlines a new plausible pathway for hominins to have initialised fire-use behaviours. Additionally, an innovative cross-cultural survey generated novel data on the attitudes and framing of fire of modern humans; information desperately needed and currently lacking from the extant body of knowledge.

Hominin fire-use is clearly visible in the archaeological record and well accepted by researchers at about 450,000 years ago (Sergant et al. 2006) and is perhaps evidence of a ‘cultural flourishing’ (Roebroeks and Villa 2011). However, all evidence prior to finds excavated at Gesher Benot Ya`aqov (~790 Ka) by Alperson-Afil, Goren-Inbar and colleagues (e.g. Alperson-Afil et al. 2007, Alperson-Afil 2008, Alperson-Afil and Goren-Inbar 2010) currently remains fiercely contested despite the growing number of sites and the breadth of evidences presented. Hypotheses asserting a hominin relationship with fire earlier than that observed at Gesher Benot Ya`aqov can be grouped as ‘early fire’ theories. However in this dissertation the case is made that the hominin relationship with fire is very deeply rooted and is much older than the Gesher Benot Ya`aqov evidence; in this study ‘early fire’ is uniquely defined as ‘any repeated deliberate hominin use of fire and wildfire created resources that predate the earliest known out-of-Africa migrations’.

Attwell et al. (2015: P14) suggested that ‘*research should focus on setting the use of fire in a palaeoecological context to test hypotheses of dispersal and niche construction*’; this study follows this ethos. Accordingly, the focus is very much on hominin fire-use pre-dating out-of-Africa migrations thus pushing the earliest hominin fire-use back to 2Ma and earlier. Hominin fire-use that predates, or is synchronous with, the emergence of *Homo* can be mobilised to explain so many behavioural social and cognitive adaptations (that are either visible within the archaeological and fossil records or deduced from analysis thereof) (Burton

2009, Gowlett 2010, Attwell et al. 2015) that it is imperative that a paradigm emerges that researchers have confidence in that removes the current mismatch between the accepted timings of hominin fire-use and key evolutionary adaptations. This study hopes to help catalyze a paradigm shift with one hoped for outcome being to help reframe the way that researchers view the pathway into the earliest deliberate opportunistic hominin fire-use.

This study argues that further plausible biological driving forces for the initial uptake of anthropogenic fire-use exists to those already in the literature (outlined in Chapter 3). As fire is a universal feature of modern *Homo* it will be suggested that the cognitive and genetic foundations were in place before out-of-Africa migrations; and that psychological behavioural relics exist within modern human populations that may help elucidate ancestral relationships with fire. In this study it is proposed that the onset of the earliest opportunistic deliberate interactions with the 'Wildfire Package' (a term coined in this study and fully defined on the next page) may even predate the earliest archaeological appearance of *Homo* (currently ~ 2.8Ma [Villmoare et al. 2015]) with the period of 3.5-2.0Ma (highlighted by Potts and Faith 2015 for its numerous stages of prolonged high climate variability, by Sponheimer et al. 2013 for dietary changes, and by Harmand et al. 2015 for technological plasticity) cited in this study as of particular relevance to the 'Fear and Flames' hypothesis (FAF). This period is significant also for the initial archaeological appearance of definitive lithic technology; a broadening toolkit can be taken to denote altering hominin cognition and adaptive niches.

For Plio-Pleistocene hominin exploitative strategies and behaviours linked to Wildfire Package affordances to classify as plausible adaptive selective forces they require the generation of sufficient adaptive selective pay-offs. While the potential benefits of fire, even opportunistic fire, to hominins are well recognised, the argument is not (and cannot be) teleological. The history of anthropogenic fire-use is undoubtedly complicated and diverse, with unknown (possibly exaptive) reason(s) for the uptake and incorporation of fire into hominin toolkits. Hominins would first have used fire passively (Burton 2009) then with greater familiarity and experience more complex fire-use behaviours and adaptations would arise; Chapter 2 includes a discussion of the nature of the hominin pathway into fire-use and the '3-stage' model of hominin-fire development. Some of the most common (and non-complex) uses of fire by modern day hunter-foragers can be instantly discounted as the initial motivation for Mode 1 behaviours as a close association with fire would be necessary before any benefits could be enjoyed; these uses include food/tool preparation and using fire as a social focus. It is argued in this study that any theory that requires continuous obligate fire-use before 'ignition at will' should also be discounted as the initial hominin fire-use behaviour. This is because of the hypothesised inability to satiate obligate fire use without being able to make fire. A detailed thought exercise solely identified very active volcanic landscapes as offering a potential solution to this conundrum (as per Medler 2011); this would then of course render the hominin group as being intimately associated with landscapes of this type.

The Wildfire Package concept

Here a new way of looking at the affordances of wildfire, termed the 'Wildfire Package', is presented to help reframe ancient hominin relationships with fire. When the initial interactions of hominins with fire (at some as yet unknown time within deep history) is conceptualised perhaps the image conjured is of a group of 'primitive people' with archaic features and behaviours looking at a fire with a mixture of fear wonderment and distrust of the unknown. However this image does not take into account notions that the very earliest utilised benefits of fire for hominins may have had little to do with fire at all, but more to do with other aspects of the Wildfire Package. In this study the Wildfire Package is viewed as having three different primary components: i) wildfire; ii) wildfire burnt environments; and, iii) wildfire created resources. Each component is viewed as having a unique set of exploitable benefits and associated risks which will be different depending on the individual characteristics of each wildfire event and the environment within which it occurs. Wildfire is a 'shape-shifter' (Pyne 2016); as it changes it offers different affordances. The Wildfire Package should be seen as 'all aspects of wildfire's impacts on the environment' and includes impacts on the distribution, structure, actions and/or behaviour of landscapes, animals and plants. The Wildfire Package offers many affordances and generatable adaptive-selective pay-offs exploitable by hominins (as per Burton 2009).

When researchers try to identify the evolutionary pathway taken to achieve the onset and stabilisation of anthropogenic fire-use then it is important to acknowledge the wide variety of ways that wildfire alters landscapes, produces new resources and modifies, or destroys existing ones, creating a wide diversity of exploitable opportunities for behavioural, cognitive and technological innovation. The Wildfire Package is viewed as a very fluid concept due to the individual nature of each wildfire and the large number of variables that can impact on the nature of any wildfire event and the local environment post-burn; therefore the ecological effects of an individual fire may be quite different from those resulting from a fire regime. This may be due to any number of different variables (biotic and abiotic) including but not limited to: the type of environment, topography, fuel load and moisture content, weather conditions, ambient temperature, relative humidity, recent rainfall levels, soil type and conditions, season, ignition source, wind direction/speed, time since last burn, time of day of ignition, level of grazing pressure, time of year, precipitation levels (Pyne 2001, Govender et al. 2006, Bowman et al. 2011). Each wildfire event should be viewed as having its own individual 'identity'; one wildfire event may create a completely different set of opportunities exploitable in a very different set of ways to another wildfire even if the nature of the landscape and resource distributions are similar.[1]

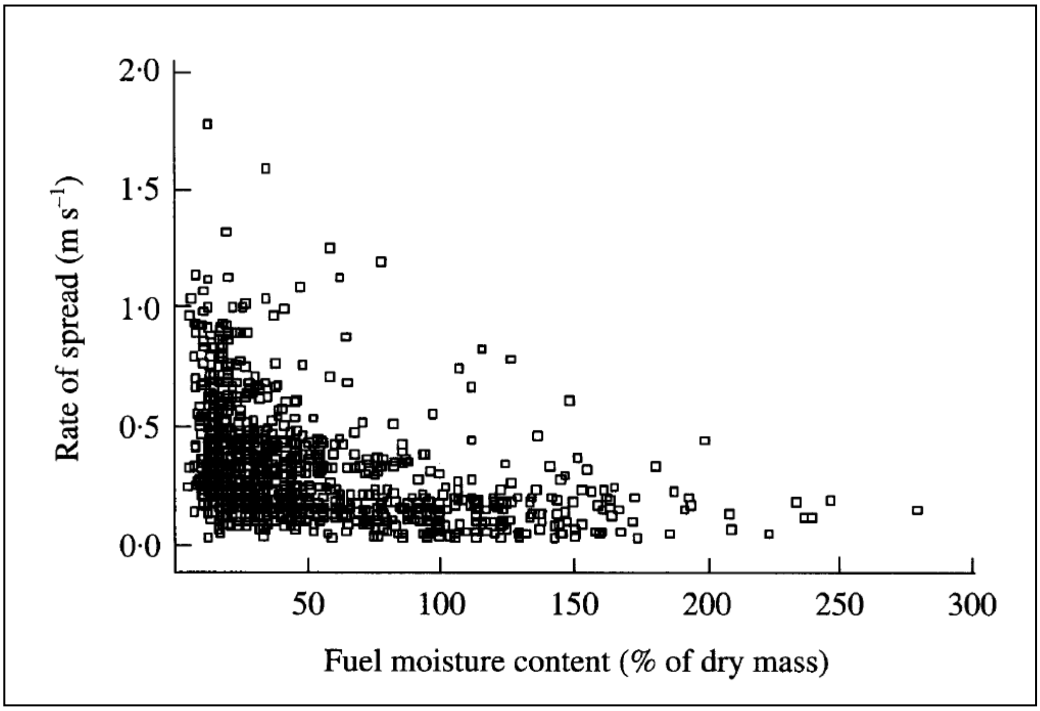
Different ecotypes may have dissimilar characteristics producing diverse results (Table 1.1) and other controlling (or directing) variables. To give an illustration of this, here one variable, fuel moisture content, is focussed upon (here data from Kruger National park is presented due to the strict scientific regimen conducted there). Govender et al. (2006) looked at the relationship between fuel moisture content and the rate of spread from 956 fires on experimental burning plots in the Kruger National Park which was identified as being closely correlated (Fig. 1.1); detailed study on other variables may provide similar results (so much so that researching this specific aspect of fire ecology could easily be a separate thesis or even an entire academic career).

Biome	Pre-industrial fire regime
Tropical rain forest	Very infrequent low-intensity surface fires with negligible long-term effects on biodiversity
Tropical savanna	Frequent fires in dry season causing spatial heterogeneity in tree density
Mid-latitude desert	Infrequent fires following wet periods that enable fuel build-up
Mid-latitude North American seasonally dry forests	Frequent low-intensity surface fires limiting recruitment of trees
Boreal forest	Infrequent high-intensity crown fires causing replacement of entire forest stands

Table 1.1: a representative cross-section of biomes from low to high latitudes with brief descriptons of identified pre-industrial fire regimes (adapted from Bowman et al. 2011).

[1] A product of this realisation is that obtaining usable high quality data from fire experimentation is a very complex time consuming process requiring multi-site, multi-year and multi-fuel research programs. A good example of this is research currently undertaken in Kruger National park (SA) that started in the 1920s (Biggs et al. 2003, Van Wilgen et al. 2003, Van Wilgen et al. 2007). In the early part of this study fire research was attempted in South Africa in 2012 to specifically gain personal observations. This research had significant impact on the direction of this study and led to the formation of the FAF hypothesis but the data was not robust for reasons mentioned previously. A brief resume of this research can be found in Appendix A.

Figure 1.1: The relationship between fuel moisture content and the rate of spread from 956 fires on experimental burning plots in the Kruger National Park (From Govender et al. 2006).



A brief outline of the Fear and Flames Hypothesis

One major aim of this thesis will be to test the Fear and Flames hypothesis (FAF), a new model developed in this study; FAF is laid out in full in Chapter 4 but briefly outlined here. To summarise FAF in one sentence would be to say: A deliberate hominin association with fire was initiated, driven and stabilised by adaptations aimed at maximising benefits and adaptive pay-offs available through 'Landscape of Fear' (defined later in this section) optimisation enabled by preferential exploitation of Wildfire Package affordances; this led to a combination of changes to hominin foraging and social strategies that facilitated reductions to required levels of investment in vigilance and other anti-predation strategies.

FAF is centred on the notion that it is not only the physical aspects of Wildfire Package affordances (e.g. high quality foraging) that could have provided hominins with significant adaptive pay-offs. FAF proposes that the adoption of a package of adaptive strategies deployed within both physical and mental landscapes enabled the successful preferential ancient hominin exploitation of Wildfire Package affordances. FAF requires viewing fire as a useful tool that has environment altering and niche building capabilities; fire should be viewed as part of a broad and diverse Plio-Pleistocene hominin toolkit. Not necessarily a physically wielded tool, but instead 'a tool in the mind' in terms of an awareness of fire's ability to change the nature of landscapes and resources and the behaviour of plants and creatures. In this thesis fire is viewed as having been 'a tool in the hominin mind' long before it was a tool in the hominin hand. Perhaps a long association with the Wildfire Package preceded active fire manipulation (Chapter 2 discusses fire's proposed 'deep root').

The FAF hypothesis suggests that ancient hominins significantly gained from constructing beneficial 'fire-based landscapes of fear'. It is predicted that relics of ancient behavioural adaptations and relationships with fire are still visible within the psychology of modern humans; an idea tested in Chapters 5 and 6 of this study (the limitations of this approach are discussed briefly later in this chapter [P40-41] and in more depth in Chapter 2). A 'landscape of fear' (LOF) is a self-constructed mental landscape that can be very influential in decision-making. It is created with 'topography' being self-generated by an organism plotting its perceived risks which are then mapped onto the observed physical landscape [Brown 1999, Brown and Kotler 2004, Laundre et al. 2010]). Within this study a hominin LOF is viewed as being formulated with inputs from inherited neural architecture and the individuals' own life experience; the LOFs of early members of *Homo* and their antecedents are also viewed as having been constructed with a mixture of 'nature and nurture' inputs. LOF theory is discussed in greater depth in Chapter 4.

There are numerous ways in which the use of fire may have impacted upon hominin evolution, with light and heat often being viewed as the two primary 'drivers' (Attwell et al.

2015); however the FAF pathway is focused elsewhere. Within FAF the breadth of high quality foraging opportunities within the Wildfire Package (e.g. invertebrate and small mammal resources, nutrient rich ash and nutritious plant regrowth) is prominent within the package of benefits outlined. The FAF hypothesis however mainly focuses on LOF affordances, specifically adaptive selective pay-offs created by adapting LOF structures to better exploit both the physical affordances of the Wildfire Package and the impacts of the Wildfire Package on the behaviour of other species, particularly large predators. It is proposed here that cognitively complex Plio-Pleistocene hominin foragers would be aware of changes to the behaviour of other species and have the brainpower to formulate strategies to take advantage of landscape-level opportunities as they arose (in line with cognitive ideas proposed by Penn et al. 2008 and Mobbs et al. 2015). Those that created or adopted adaptations to benefit from opportunities would be rewarded with adaptive selective pay-offs and increased biological fitness; the mechanisms that drive the spread and stabilisation of novel traits and behaviours (Campbell and Reece 2005).

Risk can equate to stress, which has biological costs (Gamble et al. 2014); strategies that reduce risk will also reduce stress which will have (potentially very significant) adaptive selective pay-offs. The FAF pathway proposes that the exploitation of Wildfire Package affordances would provide a combination of significant vigilance reduction opportunities as well as a suite of foraging options (which may be enhanced by vigilance investment reductions), and therefore opportunities to maximise foraging intensity and returns (e.g. obtain high quality resources) while innovatively managing risks. FAF specifically focuses on adaptations within mental landscapes that would enable effective exploitation of Wildfire Package affordances; this is an innovative perspective on the origins of hominin fire-use.

The FAF hypothesis can help explain mismatches between the palaeoclimatic record and encephalisation trends by showing how the Variability Selection hypothesis of Potts and colleagues (outlined in Chapter 2) can set in motion processes, relationships and trends that eventually result (after a long time-lag) in encephalisation and out-of-Africa migration. FAF should be classed as a 'pyrogenesis hypothesis', in that the onset of fire-use is proposed to have subjected ancient hominins to new adaptive selective forces which altered the trajectory of hominin evolution (as per Medler 2011). FAF specifically proposes that aspects of hominin fire relationships are ancient and predate the emergence of *Homo* and that hominin fire-use is a key construct of the *Homo* niche; concepts that can help to explain the nature of modern human relationships with fire. FAF requires viewing the utilisation of the Wildfire Package as containing a complex package of exploitable opportunities that can be converted to benefits with attached (potentially very significant) adaptive selective pay-offs.

FAF argues that a more nuanced viewpoint looking specifically at the ***impact of wildfire on landscapes and the nature of available resources*** may provide new insights into how ancient hominins evolved in the way that they did, resulting in a genus that could colonise new continents. Given the acknowledgment that lithic tool use impacted hominin morphology (e.g. the hand) (Marzke 2013 *passim*, Kivell 2015 *passim*) the concept of the earliest hominin fire-use being related to fire 'as a tool in the mind' is proposed to have left identifiable traces within modern hominin cognition.

Wildfire Package Affordances

A Wildfire Package affordance of particular focus is the open nature of many wildfire environments and the much clearer field of view that they offer (as per Herzog et al. 2014). One FAF pathway highlighted in this study relates to the opportunities that the Wildfire

Package offers to provide safe, intriguing, rich learning environments usable as nurseries/ social space for child-carers and curious juveniles (outlined in Chapter 7). FAF proposes that it was the use of information generated from social and associated learning that enabled fire-based LOF benefits to be identified and achieved. Adaptations then spread and stabilised due to the strength of the selective forces generated by a range of significant pay-offs. At the heart of FAF lies the proposition that it was adaptively significant mental benefits (measured in reductions to stress and fear levels and associated subsequent reductions in vigilance investments) that proved advantageous to ancient hominins resulting in the initiation of hominin fire relationships.

Given the sheer diversity of threats and risk that migrating hominins must have encountered when leaving Africa and colonising swathes of new environments, migrating hominins must have taken with them a flexible system of neural architecture that was highly adapted to successfully assess and manage risk (Mobbs et al. 2015). In this study the role of the utilisation of Wildfire Package affordances as a way of both effectively managing risks and reducing the required investments to successfully manage risks is focussed upon as well as the implications of these strategies on the cognition of ancient hominins and thus modern humans. Potential benefits accruable through the FAF pathway include:

i) Reduced levels of *intra*- and *inter*- specific predation
ii) Significantly increased social time
iii) Significantly increased opportunities for parental investment
iv) Significantly increased dietary quality
v) Significantly less stressful fearful lives
vi) Numerous opportunities to experiment with new highly beneficial strategies (e.g. smoke-assisted honey-collecting)

vii) Increased cooperation and/or the development of new social structures

These potential outcomes should not be viewed in isolation, but instead should be seen as a package with the nature of the package being dependent on (amongst other factors) the specific characteristics of the local Wildfire Package (and related affordances), and also the regional cultural and behavioural traditions used to exploit them. It is hoped that by modelling stress-reduction strategies (measurable in reduced investments in vigilance) in tandem with a foraging/lifeway model (which proposes a number of affordances that help meet energy, social and nutritional budgets), a suite of adaptive-selective pay-offs measured in nutritional or social benefits can be generated (e.g. enhanced ability to balance energy cards, more time sleeping or socialising with kin/offspring). FAF proposes that this approach can better explain the onset of hominin fire relationships than already published theories.

In this study a set of three criteria are created and applied to existing theories (see Chapter 3) regarding the initial uptake of hominin fire-use to expose strengths and weaknesses and to identify concepts that new theories must embody to be able to negate the kind of attacks that current theories appear susceptible to. FAF conforms to all three of the criteria for accepting the viability of an early fire theory. FAF: i) fits with respected evolutionary theory; ii) is plausible from the perspective of a non-fire-using hominin; and iii) does not directly result in obligate fire. These criteria were a clear constraint on the construction of FAF. By stating specifically that the earliest parts of FAF predate, or at the latest, are synchronous with the emergence of *Homo* this places the advent of fire-use as a significant causal factor in the emergence of increased levels of hominin co-operation, eurytopy and sociality. FAF paves the way for the numerous previously suggested societal and cognitive changes required by obligate fire-use (e.g. Wrangham 2009 and Twomey 2011). As detailed in Chapter 4, FAF is the only currently available model that fits these criteria and allows *Homo* to leave Africa with a genomically expressed relationship with, and attraction to, fire that does not require obligate fire-use; importantly the FAF pathway prepares the hominin brain for obligate fire behaviour but does not result in it.

Hypotheses like The Social Brain theory (Dunbar 1998, Dunbar et al. 2010) and the 'Cooking Hypothesis' (Wrangham 2009) postulate a much earlier use of fire than is so far visible in the archaeological record. Thus far, direct evidence has proven insufficient and indirect supporting evidence must therefore be incorporated into any attempt to construct a resilient case for early fire. The FAF hypothesis was specifically constructed to avoid the theoretical weaknesses of other models previously advocated for the uptake of anthropogenic fire-use (discussed in Chapter 3). It is obviously impossible to examine first-hand the thinking, attitudes and mind-set of extinct species of hominins such as *Australopithecus sp*. and the numerous species that make up the genus *Homo* living prior to 1.8Ma (or not so numerous depending on a 'lumping' or 'splitting' perspective). Therefore researchers must resort to different strategies, including: i) analyses of the archaeological or fossil record; ii) studies on extant primates; or iii) investigations on extant modern humans. All of which have their respective weaknesses. It is expected that numerous studies in these areas (including studies that combine these approaches) may be required to enable the research community to have confidence in this approach, the data that they generate and conclusions drawn.

Due to a number of factors (e.g. the low preservation potential of fire, the fact that the earliest hominin interactions with fire would have been with wildfire and therefore would be indistinguishable, and the nature of the 'bar' set by researchers for archaeologically identifying fire), analyses of the archaeological or fossil record have failed to sufficiently address the earliest hominin fire interactions. Publication of papers such as White et al.

(2015), on the pitfalls of using extant primates as referent models for ancestral hominins such as *Australopithecus* and (early) *Homo*, has further cast into doubt studies and methodologies that mobilise extant primates as analogues of ancient hominins (the limitations of this approach are further outlined in Chapter 2).

An introduction to the survey fieldwork and data collection

Therefore in this study the third approach, an investigation on extant modern humans has been taken. This presents the main focus of this dissertation and is viewed here as the main contribution that this study makes to widen the extant body of scientific knowledge. A major aim of this research is to fill a gap in our knowledge of current human behaviour which will then aid understanding of ancient behaviours and their origins. ***Accurately knowing what current attitudes to fire are seems really important, however what appears particularly lacking from the extant body of knowledge is how people perceive fire today in terms of risk***; ***this study directly approaches this issue***. It does so in the knowledge that human decision making is affected not only by rational calculations of material pay-offs, but also by emotions (Puurtinen and Mappes 2009) many of which are inherited (Mobbs et al. 2015). The data collection and analysis part of this thesis is a cross-cultural comparative investigation into the fire-related LOFs of modern humans. The psychology of fire and particularly the attitudes to fire and the active framing of fire by modern humans has been little studied (but see Murray et al. 2015 for a recent review); what little research has been conducted often focused on arson and fire-playing (e.g. Simonsen and Bullis 2001, Pinsoneault 2002, Cotteral 2003, Perrin-Wallqvist and Norlander 2003, Murray et al. 2015). To date no one has conducted and published a cross-cultural exploration and quantification of attitudes to, and the framing of, fire by modern humans to establish what cross-cultural trends exist. This is rectified in this thesis.

This study has attempted to address this issue with the deployment of an innovative cross-cultural comparative questionnaire data collection exercise looking at attitudes and perceptions to fire to generate data to test aspects of the FAF model (See Chapter 5 for methodology, Chapter 6 for results and Chapter 7 for application of results to the FAF hypothesis). This study recruited cohorts from three very different populations with dissimilar ethnic and socio-economic backgrounds. This was to help tease out reasons for between community differences and, importantly, so that 'universal' trends (if present) could be illuminated; ideally more communities would have been surveyed (see 'future research direction and opportunities' in Chapter 8) but as a Ph.D study, resource and time limitations applied. One cohort was recruited from very recently hunter-gatherer Ugandan Batwa communities (now subsistence farmer/labourers [N=225]), another from a population of urban educated non-Batwa Africans (predominantly from the Bachega and Bufumbira tribes living in and around the Ugandan town of Kabale [N=219]), while the third cohort consists of a broad sample of the UK population (N=217) partly recruited using a simple 'snowball' methodology.

This study used qualitative research methods to identify participants' use of fire during their lifetime, how they feel about fire and the relative strength of those feelings.

This study aimed to specifically observe and quantify the fire-based LOF of the Ugandan Batwa and then compares them with another geographically proximal African cohort and also a cohort from the UK. Fieldwork was conducted between December 2014 and March 2015 in the UK and in November and December 2015 in Southwest Uganda. It was broadly hypothesised that the risk based framing of fire by hunter-gatherers will be closer to ancestral relationships and that a cross-cultural 'positive framing' of fire would be identified; a complete list of postulates and hypotheses is provided in Chapter 5. It was hoped that the cross-cultural comparison would identify similarities and differences between the three cohorts that would highlight the impacts of modern life on attitudes to fire, but also identify trends, patterns and relationships that would illuminate ancestral framing of fire, how fire would have fit into the Landscapes of Fear of ancient hominins, and hopefully point towards the nature of the pathway that led to the onset of deliberate hominin fire relationships.

At the beginning of this thesis it is important to clearly set the agenda of this study. This study, while being focused on the nature and timing of the onset of the earliest deliberate hominin relationships with fire, also attempts to remedy the fact that too little is known about modern attitudes to fire, and how fire-associated risks are perceived and framed. A review of the literature (laid out in detail in Chapter's 2 and 3) show that's a number of important questions regarding the nature and timing of the start of this fundamentally important relationship remain unsatisfactorily answered. The overall objective of this study can be split into two broad categories: i) Theoretical aims; and, ii) Fieldwork goals (which aim to provide data with which to test specific aspects of the results of theoretical work). Fieldwork goals are aimed at addressing the broader theoretical aims through systematic hypothesis testing.

The importance of psychological states in early fire research

When attempting to model the psychological journey required by hominins to become fire-users researchers must be sure to distance themselves from projecting modern attitudes and relationships with fire onto ancient hominins; this is often more easily said than done. Familiarity has been suggested to be a necessary precondition for any emergent behaviour in which fire is approached and its affordances evaluated (Attwell et al. 2015). To successfully exploit Wildfire Package affordances it appears imperative that appropriate complex psychological and mental relationships with fire exist (Goudsblom 1986, Fessler 2006). Technological and morphological developments need to be matched and accompanied by mental processes, thus suggesting that the onset of hominin fire-use is best seen as a 'socio-psychological' process (Goudsblom 1986). For hominins to benefit from aspects of the Wildfire Package appropriate psychological relationships with, and responses to, fire must be adopted. This study argues that this was the prerequisite initial step leading to effective exploitation of Wildfire Package affordances and would require the ability to conceptualise fire (as proposed by Pruetz and LaDuke 2010).

Direct evidence for Plio-Pleistocene hominin cognitive processes does not exist (Sherwood et al. 2008, Shultz et al. 2012). Instead behavioural abilities are viewed opaquely through archaeological remains with inferences made from available material (as per Twomey 2011). While encephalisation is often focussed on as evidence of cognitive change, major hominin cultural innovations are not necessarily linkable to increases in cranial capacity (Sherwood et al. 2008). Even in the absence of significant changes in brain volume, subtle modifications in neural microstructure and gene expression can have significant impacts on behaviour (Sherwood et al. 2008). In this study the 'very deepest tip' of the 'root' of hominin fire-use is hypothesised as psychological in nature and linked to energetic and time budgets. Through hereditable DNA encoding for the production of hormones and proteins that direct behaviours, psychological mechanisms are a method of behavioural adaptations becoming hardwired into primates; the synthesis and production of which are controlled by specific genes and combinations of genes (Mobbs et al. 2015)[2]. The idea of a very deep root for hominin fire-use should not be thought of as a 'habitat-specific hypothesis' as criticised by

[2] This is in addition to epigenetic changes that can occur within the genome of individual organisms during its lifetime

Potts (1998). Instead it can be viewed as part of a range of 'landscape optimisation strategies' that would have enabled hominins to thrive in unstable environments.

All fire researchers, those who support 'early fire' and those who do not, can agree that fire has been a strong selective pressure shaping the course of hominin behaviour (it is merely when this occurred that researchers disagree upon); by necessity psychological mechanisms underlie hominin-fire relationships (see Chapters 3 and 4). One psychological mechanism required would have been the deployment of self-restraint when flight/stay decisions are required (Goudsblom 1986); a wrong decision could have serious implications for the individual or group (Mobbs et al. 2015) as often the costs of not effectively fleeing are significant (e.g. injury/mortality). To make this decision requires high quality information and the ability to process it effectively. The greater the frequency of interactions with fire then the more information is processed and stored. Repeated exposure builds stimulus-response associations resulting in specific behavioural reactions (Smith 2011). Most animal behaviours are explainable in terms of adaptive innate, or learned, stimulus-response associations that have become reinforced over time (Twomey 2011). An ability to recognise the specific nature and characteristics of each individual fire (e.g. fire intensity and course) would be required to be able to conceptualise the future behaviour of the fire and plan accordingly; many cues would be available to help (e.g. behaviour of other animals and birds). This suggests that even the simplest forms of Wildfire Package exploitation require specific cognitive capabilities, and these need further study.

Why 'early fire' is approached in the manner undertaken in this study

The theoretical foundation for the approach taken in this study derives from the acknowledgement that natural selection favours individuals who were motivated to explore and utilise environments likely to afford the necessities of life (Han 2007), and to avoid environments with poorer resources or those that pose higher risks (Orians and Heerwagen 1992, Cowlishaw 1997). ‘Habitat selection theory’ states that selecting appropriate settings is an essential and necessary activity for animals (hominins included) due to the close relationship between the successful survival, reproduction, and well-being of a community or species and habitat (Kaplan 1987, Kaplan and Kaplan 1989, Orians and Heerwagen 1992).

Fire is widely seen as a source of fascination in modern societies, despite the damage and destruction that it causes (Murray et al. 2015), and despite the fact that for many sections of society it remains hidden (Pyne 2016). It is proposed here that understanding why modern humans frame fire as they do requires direct observation and quantification. As the neural architecture of modern humans has been suggested to have developed to cope with environments and situations faced by recent and ancient ancestors (Sherwood et al. 2008, Mobbs et al. 2015) increased knowledge of modern human attitudes to fire should aid greater understanding of ancestral relationships. However this study cannot, and does not, suggest that knowledge of modern human attitudes to fire can fully illuminate ancient hominins thinking.

The discipline of Evolutionary Psychology (EP) provides viewpoints and information used in this thesis, but it has also previously generated substantial controversy and criticism (Plotkin 2004, Tooby et al. 2005, Confer et al. 2010, Barrett et al. 2014) some of which is also directly pertinent to this study. Previous criticism includes: the significant issues that exist surrounding the testability of evolutionary hypotheses (as per Confer et al. 2010 – which were also faced in this study); EP struggles to cope with the fact that alternatives exist to some of the cognitive assumptions made frequently employed in evolutionary psychology (e.g. massive modularity) (Plotkin 2004); some EP assumptions are relatively unsupported (including the specific nature of ancient hominin environment[s] of evolutionary adaptation) (Tooby et al. 2005). EP has not yet adequately engaged with the rapidly developing field of epigenetics (Lickliter and Honeycutt 2003); perhaps because this field is so new and often relatively misunderstood. Some of these ideas are further critiqued in Chapter 2.

However in defence of EP some of its critics seem to prefer to concentrate criticism on terminologies used, often misinterpreting definitions, paraphrasing researchers out-of-context or focussing on a specific aspect that they purposefully reframe to highlight their own agenda (e.g. see Barrett et al. 2014 for numerous specific examples of these kinds of behaviour), and delight in the contruction and subsequent destruction of *straw men* (as per Confer et al. 2010). This seems to be at the detriment of the basic overarching principle that each species is a product of their evolutionary history (Bauman et al. 2012, Gibson and Lawson 2014). It is argued here that the benefits of utilising a highly integrative and pluralistic field that can '*provide new insights into the ultimate motivations and proximate pathways that guide human adaptation and variation*' (Gibson and Lawson 2014; 1) are many. For example, Bouchard and Loehlin (2001) make a convincing case that EP can help to reveal the underlying neural determinants of certain personality traits. Additionally many public health researchers believe strongly in some of the core tenets of EP (e.g. Omenn 2010 and Bauman et al. 2012); although it should not and cannot be used to fully explain any perceived or apparent correlation or relationship.

Provided researchers are aware of the criticisms and weaknesses of this approach in this thesis it is proposed that research along the lines proposed can significantly help the study of ancient behavioural changes; particularly when more traditional methodologies cannot hope to adequately address the topic on their own. Therefore in this study the theoretical stance that underpins fieldwork research conducted as part of this study is that fire is so fundamental to being a member of the genus *Homo* that responses will be driven by a relationship so imbedded within our neurological architecture that some responses to, and framing of, fire will be affected by hardwired attributes than underlie personal and cultural experience.

If deliberate opportunistic relationships existed between Plio-Pleistocene hominins and Wildfire Package affordances that were capable of generating significant adaptive selective forces acting in vital areas of paleoecology such as group size/structure, diet and habitat choice (all of which exhibited significant changes during the emergence of *Homo*), then, it is proposed here, this relationship would be embedded so deeply (with)in the behaviour and cognitive processes of this genus that identifiable psychological remnants would be likely to persist (but see Chapter 4 for some caveats – particularly the discussion on the plasticity and modularity of neural pathways). It is argued here that the nature of the earliest hominin fire relationships may have impacted on the nature of the neural circuitry of modern populations and therefore modern attitudes to, and framing of, fire. This acknowledgment can be reorganised to say that trends and relationships observed within the thinking of modern humans are capable of illuminating the nature of ancient fire relationships, at least to some degree. Modern attitudes to, and perceptions of, fire will be generated by psychological mechanisms that exist because they solved adaptive problems in ancestral environments in which the human line evolved.

Early fire theories are constructed on the notion that the archaeological record and the course and nature of the evolution of *Homo* can more easily be understood by mobilising fire-use than by denying it (Gowlett 2010, 2016). Early fire theories mobilise the deliberate opportunistic use of fire by hominins before it is visible in the archaeological record and therefore push the use of fire much deeper into prehistory. Early fire theories are supported by a number of morphological and behavioural adaptations (e.g. reduced gut size, encephalisation, changes to community structures and interactions, levels of parental investment, loss of body hair) identified by analysis of the fossil record and other archaeological material (Burton 2009, Wrangham and Carmody 2010, Gowlett 2010) as appearing and stabilising before the appearance of hearths. Hearths have been until recently widely accepted as the principal evidence used to seek out anthropoid primate fire-use (Clark and Harris 1985, Bellomo 1993, Gowlett 2010) and are often the most valuable archaeological indicator of hominin fire-use, but they also may be only a small part of the picture. However, without the identification of a dated incontrovertible hearth, to argue successfully for anthropogenic fire-use in the early Pleistocene or late Pliocene and gain credence amongst the wider research community requires the production of more than solely parsimonious analyses; good quality data generated by robust methodologies is required.

To date attempts to observe ‘early fire’ have mostly relied on archaeologically based studies, but direct incontrovertible evidence of ‘early fire’ has proved difficult to obtain. This is a serious problem as finding archaeological evidence has for some time been considered crucial to the creation of a resilient ‘early fire’ case (Clark and Harris 1985). It has been thought likely that if hominins were using fire they would concentrate activity around it in order to gain maximum value (e.g. protection, heating and lighting). Direct archaeological evidence has been sought in many forms, including: knapping residues, lithic technologies, signs of butchery, as well as hominin dental and osteological remains (Clark and Harris 1985). However, due to the preservational potential of fire residues perhaps allied with a lack of knowledge as to how fire fitted into the social structures and behaviour of community’s (e.g. was fire and other activities like knapping kept separate or ‘off-site’ as proposed by Dibble et al. 2017 for some Neanderthal groups), the archaeological fire record is often characterised by the lack of fire evidence where it should be (Wrangham 2009) even amongst the relatively modern record (Sergant et al. 2006). Chazan (2017; P-S354) even goes so far as to state that "*One of the greatest hazards in the study of early human interactions with fire is the possibility that during some periods the activities related to the use of fire would have been spatially distinct from the activities that result in the accumulation of large assemblages of stone tools and faunal remains*." Chazan (2017) isolated and identified a clear methodological weakness of ***traditional archaeological approaches*** to the study of the origins of hominin fire-use. Perhaps integration of methodologies from other scientific areas can help to more fully address and illuminate this important palaeoanthropological area.

Another issue that has recently started to gain increasing traction and importance is the concept of 'off-site' fire use and its potential role in the complex history of hominin fire-use. 'Off-site' fire-use is here taken to mean the use of fire away from a home-base or residential setting. According to Scherjon et al. (2015: 311) off-site fire use by hunter-gatherers and traditional subsistence practitioners is currently omnipresent and is carried out by both genders and by individuals and groups of all sizes. However in this study the earliest hominin fire interactions are solely focussed upon; no clear distinction between on-site and off-site fire-use can be made as on-site use is not yet clearly attested. however the nature of off-site hunter-gatherer fire-use is discussed in Chapter 4 with reference to its implications on the Fear and Flames hypothesis. What would be interesting to know is whether the onset of hominin fire-use impacted upon or accelerated the fixation of the hominin concept of homebases and therefore in itself created this distinction. It is therefore possible that if the earliest hominin fire interactions are very deeply rooted this may actually predate the existence of the concept of on-site (and therefore the concept of off-site as well). What may be of interest to the FAF hypothesis is the idea that off-site fire practices (such as fire-stick farming [Jones 1969]) may have in part been have been developed to build upon, or create, positive landscape of fear (LOF) features. This idea is returned to in Chapter 4.

In conception this research project has, from inception, not attempted to look for direct archaeological evidence of fire, as it is not until the emergence of highly complex (Mode 3 – see Chapter 2) fire-behaviour that robust archaeological evidence has been unequivocally identified. At the start of this study it was realised that in the absence of incontrovertible direct archaeological evidence the only way to overcome the difficulties of dating and proving the existence of the very earliest hominin fire interactions would be to develop and deploy an alternative methodology to explore early fire paradigms. This alternative methodology is presented in tandem with a coherent evidence-based case for a paradigm change in how researchers view the earliest opportunistic deliberate repetitive hominin fire interactions. An important early step in this process was to try and pin down the kind of very simple activities viewable as credible non-teleological strategies that generate significant adaptive pay-offs and are capable of generating adaptive-selective forces (see Table 2.1). This study clearly acknowledges that there are limitations and inherent weaknesses in the strategies chosen (discussed where relevant throughout this study) including that, in the absence of other referent models, ethological observations and examples are at times employed (further discussed in Chapter 2). These are used to both set the scene for FAF and to support the case that a deeply rooted psychological attraction to fire exists within hominins; an idea previously espoused at length by Burton (2009). Observations on omnivorous generalist primates show how even small brained creatures are able to exploit landscape level changes wrought by wildfire for foraging and psychological benefits (Enstam Jaffe and Isbell 2009, Herzog et al. 2014). The ability to utilise a broader range of resources, opportunities and landscape-level affordances by definition will increase the eurytopy of a community; a broad toolkit was presumably an important prerequisite for ‘within-Africa’ migrations, but especially *Homo’s* out of Africa exploits which required the colonisation of new ecotypes and environments.

In cognitive terms to be able to benefit directly from wildfire (rather than other aspects of the Wildfire Package) a hominin would presumably need to be able to predict what a wildfire is going to do. This presumably entails: i) being aware of environmental factors such as wind direction; ii) having the necessary experience and cognitive capacity to assess the size, strength and intensity of the conflagration; and, iii) having the necessary landscape knowledge to know of the whereabouts of refuges as well as potential topographic features, such as chasms or large rivers, that may impede flight. Previously, attempts have been made to estimate the cognitive capacity, or brain power, of ancient hominins based on assessments of cranial capacity (e.g. Tobias 1988) or by looking at the quality, nature and/or ‘chaine operatoire’ of lithic technology (e.g. de Beaune 2004).

Without direct observation of specific behaviour around a wildfire it cannot be categorically stated that Late Pliocene hominins, or even Early Pleistocene *Homo’s,* environmental awareness included awareness of the nature of wildfire and the ability to sufficiently accurately predict its behaviour to stay safe and benefit from opportunities presented. However, recently published evidence from Dmanisi showing that relatively small brained hominins migrated out of Africa prior to 1.7MA (Ferring et al. 2011, Lordkipanidze et al. 2013), coupled with the undoubted existence of lithic technologies from these same hominin groups, is proposed here as sufficient evidence to accept that such hominins could feasibly also have had awareness of the Wildfire Package and its affordances. It will be argued in this study that by 2Ma some successful communities of hominins would have had sufficient mental acumen and knowledge and experience of the Wildfire Package to identify low and high-risk fire situations, react accordingly, and benefit from opportunities presented.

Over the past decades archaeology's working hypothesis appears to have been that fire-control demands advanced cognition not proven to be essential to early hunter-gatherer subsistence, and hence did not exist unless it can be proven beyond all reasonable doubt (Gowlett and Wrangham 2013). An idea requiring brief discussion here is: What would happen if the debate was 'flipped' over? By turning the question upside down and arguing that, rather than having to prove the case for 'early fire' with archaeological excavations and in-depth analyses of the hominin fossil record, given the changing nature of hominin niches in the Late Miocene (Messinian) the Pliocene and the Early Pleistocene, how likely is it that (increasingly more intelligent?) primate foragers would ignore all the opportunities afforded by the Wildfire Package? To support this question (and the broader theoretical stance taken in this study) in Chapter 4 this question is directly addressed by presenting a detailed synthesis of the fire related behaviours of extant anthropoid primates (and some monkeys). This was thought a better strategy than attempting to plunder the archaeological record for debatable inferences and clues as to the environmental awareness of Plio-Pleistocene hominins, which also would have been subject to potentially significant intra- and inter- species variation. One point that should be made here is that different species of ancient hominins effectively habitated a range of (often mosaic) environments (White et al. 2015) and successfully navigated (on a species level) the multiple and diverse risks in each clearly demonstrating survival intelligence and environmental awareness.

Members of the hominin lineage that includes *Homo* and their immediate antecedents seemingly had ample opportunity to interact with wildfire and wildfire burnt environments. Wildfire so clearly alters the distribution and nature of resources, the nature of the landscape and the opportunities afforded by that landscape (Herzog et al. 2014); in addition those attempting to carve new niches in changing environments must display heightened behavioural plasticity (Odling-Smee et al. 2003). Would such opportunities as those provided by numerous and seasonal wildfire and wildfire burnt environments be so wilfully ignored by countless generations of ancient hominins? Were ancient hominin niches so bountiful, easily inhabitable and stable that opportunities for biological fitness enhancement need not be taken up? The archaeological record suggests not. Perhaps proponents of 'early fire' would benefit from producing work based in some part on this line of reasoning.

To more successfully make a case for 'early fire' researchers need to re-orientate their research away from looking for ancient hearths, burnt bones and sediments and start looking at landscapes and how Mode 1 (defined in Chapter 2) opportunistic fire-use would link in with the palaeoecology and socioecology of hominins; this may be the best way to move on from prevailing 'what you see is what there was' paradigms. An understanding of diet and the foraging strategies deployed to attain this diet is fundamental to understanding the ecology and evolution of early hominins (Foley 1993, Organ et al. 2011). This is perhaps especially pertinent to the transition into *Homo*.

Mode 1 fire-use can be seen as a prime candidate for fuelling or helping to fuel the encephalisation trend (from ~500 to 1,000cc) observed in the archaeological record that occurred between 2Ma and 1Ma (Gowlett 2010); as yet undiscovered or unpublished fossil material may eventually push encephalisation trends further back into antiquity. Following lines of reasoning laid out in this thesis FAF shows how, through exploitation of Wildfire Package affordances, either an increase in dietary breadth and dietary quality can be achieved, or how energy and nutritional cards in resource scarce times can be balanced. Helping to obtain the required amount of nutrients and calories is not the only potential

benefit of Mode 1 fire-use; other fitness benefits may be present in terms of anti-predation and risk-reduction strategies, as well as other strategies that enhance survival chances.
A more nuanced 'landscape perspective' enables a range of different driving forces and opportunities to be considered and evaluated. This is essentially the quantification and analysis of the benefits possible from exploitation of Wildfire Package affordances whether it be from the fire itself, the heat, the smoke, resources created or made more easily identifiable by the wildfire, changes to the landscape, or other factors of the wildfire such as the impact on other species or groups of species (e.g. browsers, grazers, scavengers, insects), or combinations of these factors.

When taking a landscape level perspective of Mode 1 fire usage, instead of trying to identify and mathematically quantify the specific benefits that strategies such as u*tilising smoke to gain increased access to resources within beehives* or *cooking food* may confer to foragers, it is instead envisaged that a blend or combination of different strategies be seen as a package together providing a combination of benefits. Different communities or groups of hominins may have had different *fire toolkits* in the same way that different groups of extant chimpanzees have *regional traditions*[3] (e.g. different termite fishing toolkits and strategies) (Whiten et al. 1999, McGrew 2004, Subiaul 2007, Whiten and van der Waal 2016). It is also entirely conceivable that different members of ancient hominin groups may have benefitted from fire in different ways (e.g. males and females); as discussed in Chapter 7.

[3] The definition of 'tradition' by Fragaszy and Perry (2003) is followed here. They define a tradition as a "*distinctive behaviour pattern shared by two or more individuals in a social unit, which persists over time and that new practitioners acquire in part through socially aided learnin*g".

Chapter 2 – Hominin fire-use – Background and problems

General Introduction

As the 'setting the scene' chapter for a multidisciplinary palaeoecological study on the origins of hominin fire-use this chapter has a lot of material to cover. In this chapter the role of natural fire as an adaptive selective force is investigated, alongside analysis of how the early fire debate has been 'framed' by researchers and some of the key terminologies used. The difficulties of researching the onset of ancient hominin fire-use are also explored. In this chapter the broad nature of Plio-Pleistocene hominin diets and the value to researchers of high quality palaeodietary insights and knowledge of foraging strategies deployed to meet hominin nutritional and energetic budgets are discussed (all of which have significant implications on behaviour and habitat selection preference and use). Within this chapter the concept of a deep root of fire-use within the hominin lineage is investigated; two scenarios, the 'ancestral risk averse scenario' and the 'very ancient awareness of the properties of fire scenario' are proposed and discussed along with a synthesis of recently published evidence and their impacts on long prevailing paradigms. Also included in this chapter is analysis and description of documented fire behaviour and strategies of apes (and some monkeys) as well as a very brief review of the ancient hominins that a 'deep root of hominin fire-use' might encompass.

Introduction to Fire

Fire can occur when the three fundamental ingredients of fire meet; oxygen, fuel and an ignition source. These fundamental ingredients have been widely available on Earth ever since land plants evolved during the Silurian, with the earliest documented wildfire evidence dated to ~440Ma (Glasspool et al. 2004); fossil charcoal indicates that wildfires began to proliferate soon after the appearance of the first terrestrial plants (Bowman et al. 2009). Wildfire has a very long and active history on this planet playing a fundamental role in ecosystem composition and distribution (Bond et al. 2005), in time becoming a core ecological process. Fire can be a highly energetic and transformative natural agent with the capacity to severely impact landscapes across a broad spectrum of ranges; fire is an agent of change and an evolutionary driver (Burton 2009). To cope with the presence of fire on the landscape many organisms, both plants and animals, have had to become fire adapted.

Currently the Earth is a highly flammable planet due to its cover of carbon-rich vegetation, seasonally dry climates, high concentrations of atmospheric oxygen and carbon dioxide, and widespread natural ignitions (e.g. lightning, spontaneous combustion and volcanoes) (Bowman et al. 2009). Despite many changes to the Earth system in the last 65Ma these factors have remained relatively constant since the proliferation of primates after the end of the Cretaceous period. Direct research on the earliest hominin fire interactions is very difficult to undertake and thus defend. While fire is a widely available natural resource, it has a very low preservation potential in the archaeological record (Barbetti 1986) making an assessment of ancient fire regimes extremely difficult and not robust to academic scrutiny. This low preservation potential has been very pertinently described as fires' *disappearing act* (Gowlett 2016; P3) as if anything survives within the archaeological record it is the effect of the fire and obviously not the fire itself.

In many environments, including savannahs, fire is an extremely important disturbance process (Keeley and Rundel 2005, Ofek 2001) affecting the distribution and amount of biomass (Van Wilgen et al. 2007), the structure of vegetation (Yarnell et al. 2007) and can in some cases determine the overall ecosystem composition (Keeley and Rundel 2005, Pausas and Keeley 2009, Taylor et al. 2012). From a mechanistic point of view fire is simply the heat and light generated by combustion, but it is also a major evolutionary driver; at the individual, species and community level both plants and animals can be (sometimes very highly) ‘fire adapted’ (Cochrane and Ryan 2009). It is not just modern humans that have learnt to utilise fire for their own ends; some plants (e.g. *Eucalyptus regnans* and *Eucalyptus. deglupta* [Tng et al. 2012]) have become so highly fire-adapted that they ‘invite’ fire in to aid in competition with other plant species (Ofek 2001). While many species use fire (some animals, insects and birds opportunistically, and plants as an evolved adaptive strategy) modern humans are the only extant creatures that systematically use fire as an energy source (Ofek 2001, Fessler 2006, Wrangham 2009). The energy saving nature of fire would have then subsequently acted as “*as an agent of evolution promoting hardwired adaptations*” according to Ofek (2001; P153); this is a concept central to the Fear and Flames (FAF) hypothesis which is fully set out in Chapter 4 of this thesis.

Opportunities for encounters between primates and the Wildfire Package have occurred since the appearance of primates to the present day, but these opportunities have not been spatially or temporally constant. The fossil record shows that by the Early-Miocene apes (e.g. *Dryopithecus*) had evolved from monkeys to inhabit forest ecosystems (Agusti 2015). In most forest ecosystems (some few highly fire-adapted exceptions may exist) fire is often not very prevalent (i.e. rare and sporadic) mainly due to the lack of readily available combustible fuel caused by the rapid breakdown of organic material and very active hydrological cycling that occurs in moist densely vegetated tropical forests. Pausas and Keeley (2009) have even suggested that a dry season to convert potential fuel to available fuel should become the fourth part of the wildfire triumvirate. It can be surmised that ‘stem’ and ‘crown’ hominins inhabiting moist densely vegetated tropical forests would still have had occasional interactions with wildfire; the frequency of these interactions, and what the hominin behavioural responses were, is open to conjecture.

In the Late Miocene and into the Pliocene global climatic changes (essentially cooling and drying trends) led to numerous new habitats and ecosystems emerging. In Africa this included the emergence of C_4 savannahs and grasslands, especially through the last 3-4Ma (Bobe and Behrensmayer 2004, Levin et al. 2004, Hoetzel et al. 2013). Swathes of tropical forest were replaced by more open mosaic habitats which can be modelled as having much more frequent fire regimes (Pausas and Keeley 2009). Amongst other processes such as global cooling and drying trends the Miocene emergence of tertiary African C_4 savannahs have now been linked to 'fire driven feedback processes' (Keeley and Rundel 2005, Hoetzel et al. 2013). Therefore the palaeoenvironmental background in which the hominins emerge should be viewed as both 'fire-adapted and fire-inhabited'.

Grass fires have dominated African grassland landscapes for hundreds of millennia (Bird and Cali 1998) so African plants have had sufficient time in which to have evolved some adaptations to aid fire tolerance (Carbone et al. 2007). African grassland plant community(s) structure has been shaped by the frequency of burns so that it can be considered as a natural disturbance (van Langevelde et al. 2003) and a fundamental part of African savannah and bushland ecosystems providing bottom-up control (Gill and Taylor 2009). For a number of reasons fire is important for the maintenance and conservation of African savannah ecosystems, including the active promotion of frequent fire by C_4 grasses, thus preventing recruitment of forest species and perpetuating the continual existence of the savannah system (Govender et al. 2006) which is beneficial for foragers that incorporate fire into their niche. It appears inconceivable that hominins could, over many millennia, adapt to (and build niches within) African savannah and bush environments and not be aware of the nature of wildfire and its impacts on landscapes and the behaviour of the flora and fauna that inhabit them. This appears especially true for any ancient hominins that inhabited the highly fire adapted Zambezian ecotype (or similar ancient ecotypes); a miombo woodland that is currently one of the largest African ecozones (the specifics aspects of the Zambezian ecotype that are deemed particularly pertinent to this study are further investigated in Chapter 4).

From this brief introduction to African wildfire it is clear that one of the environments inhabited by Australopiths and *Homo* prior to the first 'out of Africa' migration included wildfire as a relatively frequently available natural resource; although it is not possible to say on a local scale exactly how frequently available it was. On a continent wide scale detailed analysis of marine cores provide some pointers (e.g. Bird and Cali 1998). As per Gowlett (2016) this study is therefore founded on the premise that hominin fire-use is an offshoot or outgrowth of far older natural fire regimes and forms part of the package of landscape-level and/or technological and behavioural adaptations that differentiates the niches occupied by *Homo* (and potentially, as discussed later in this study, precedent ancestors of *Homo* going back towards the LCA with *Pan* [and conceivably beyond]) from the niches occupied by other great apes, both extinct and extant.

Pollen data shows that acceleration in the long-term trend of C_4 grassland spread after 2.5Ma coincides with an increase in seasonal variation in climatic and environmental conditions (Foley 1993, Segalen et al. 2007). As grassland wildfire regimes are highly seasonal (being particularly prevalent after a period of low or no precipitation) (Bajocco et al. 2010) most Plio-Pleistocene hominin deliberate exploitation of Wildfire Package affordances should be viewed as a distinctive seasonal adaptation that may be causally linked to increasingly acute seasonal resource scarcity. Seasonality has led to seasonally different foraging strategies being observable in the behaviour of referent models (e.g. extant apes and human hunter-gatherers) (Foley 2001); for example, seasonal differences are visible in day range length among female chimpanzees at Gombe (Goodall 1986). Plio-Pleistocene hominins may have had to significantly adapt their diet and lifestyle to survive seasonal resource scarcity (Lovejoy 1981, Wrangham and Peterson 1996) (e.g. Paranthropines – robust prognathic jaws and megadontia are potentially an adaptation to survive seasonal resource scarce conditions rather than being purely indicative of their normal diet [Williams 2015]).

Foraging strategies and dietary variation

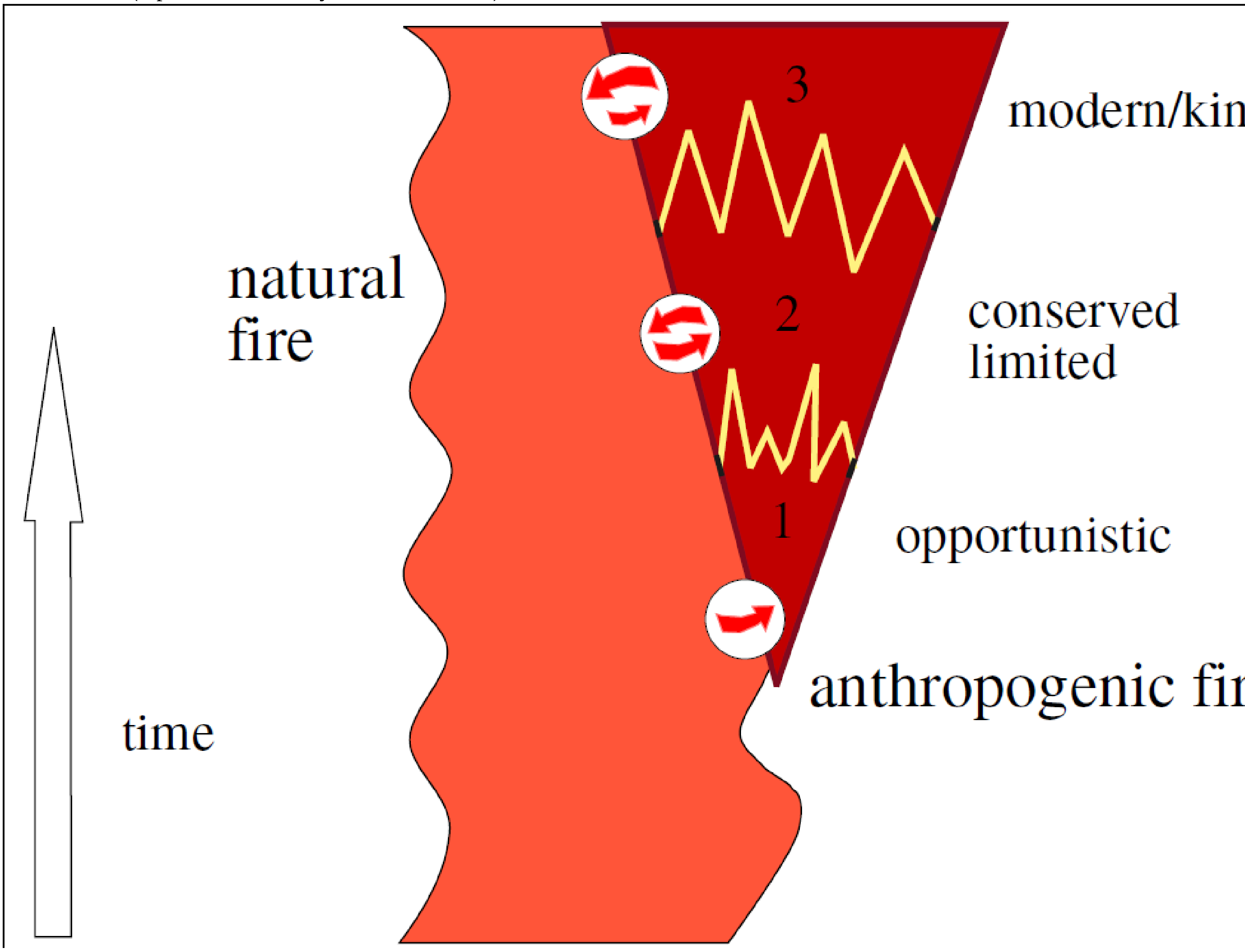
All primates show considerable seasonal dietary variation, especially in highly seasonal areas (Foley 2001). Humans differ from most other primate species through being more omnivorous, with nutritional requirements that reflect past adaptations to high quality diets (Foley 2001, Wrangham 2009). Diets of modern humans have greater energy density than those of other primates of similar body size (Leonard and Robertson 1992). If we assume that *Homo* has always deployed a ‘human-like’ foraging strategy (as per Leonard and Robertson 1992) and had roughly similar energy requirements (Aiello and Key 2002 calculated the daily energy requirements of *H. erectus* to be within 10% of that of *H. sapiens* for both sexes) then we can assume that this greater dietary energy density is a trait of *Homo* and therefore a key construct of the *Homo* niche, the deepest roots of which should predate the emergence of *Homo*. High dietary energy density is fundamental to brain enlargement hypotheses (e.g. the Social Brain theory) which all require a high quality diet (Dunbar 1998, Wrangham and Carmody 2010). It is proposed here that effectively balancing high energy budgets requires intelligent exploitation and utilisation of landscapes affordances and available resources.

There would not have been a single hominin strategy to deal with the challenges posed by rapidly evolving ecosystems. Mosaic African habitats would have led to a patchwork of populations with distinctive adaptive characteristics as observed in modern Panins (Whiten et al. 1999). Despite these ecological challenges, relative to its antecedents *Homo* appears to be/have: i) highly adapted to deal with challenging conditions (Wood and Richmond 2000); ii) increased eurytopy (Attwell et al. 2015; iii) improved dietary quality (Foley 2001, Ungar et al. 2006); iv) increased offspring investment (through processes such as increased parental investment or alloparental investment) (Key 1998, Panter-Brick 2002, Pontzer 2012, Anton et al. 2014); v) undergone a trophic reorganisation, rising to the uppermost levels of the foodweb (Bunn 2001), and; vi) increased group size (Wood and Richmond 2000). The adoption of 'early fire' can be modelled as fitting well with all of these observations and provides some requirements for the Fear and Flames hypothesis presented later in this study.

Modelling the different stages anthropogenic fire-use

It appears necessary to state clearly what is meant by hominin fire-use. Many different forms and kinds of hominin fire-use exist, commonly grouped into three different 'modes'. The concept of a three-stage model of anthropogenic fire development was clearly outlined by Goudsblom (1986) and has existed since at least the 1930s (e.g. Frazer 1930). Gowlett further refined and updated this model in 2010 (Gowlett 2010) and 2016 (Gowlett 2016) by providing a *general outline* for the development of fire-use as part of the Social Brain hypothesis (but see also Rolland 2004 and Burton 2009). By 2016 Gowlett's tri-modal general outline had become: 1) Opportunistic; 2) Conserved/limited; and, 3) Modern/kindled (Fig. 2.1). This Ph.D study focused on exploring and illuminating Mode 1 (opportunistic use) and the evolutionary drivers that could have driven hominins to preferentially search for Mode 1 opportunities, a stage viewed as a prerequisite for the advent of Mode 2. More recently Chazan (2017) appears to have 're-invented the wheel' by rehashing the three-stage model without contributing anything new other than naming stage three 'enclosure of fire' (P – s355) as opposed to 'creation of fire'. Perhaps however a 'four-stage model' with stage one being something akin to the 'habituation of fire' would be more appropriate. In this thesis this extra stage is referred to as 'fire's root; and it may be very deep indeed.

Figure 2.1: A simple schematic showing the three prescribed modes of anthropogenic fire and basic interactions with wildfire (reproduced courtesy of Gowlett 2016)



The lack of archaeological visibility of the earliest stages of hominin fire-use

Attempting to prove archaeologically the existence of and date the earliest hominin Mode 1 fire-use has, with currently available methodologies, proved impossible to deduce from physical evidence of wildfire. All fire has a low preservation potential in the archaeological record due to the effects of pedogenetic, diagenetic, aeolian and fluvial processes (Preece et al. 2007) as well as scavenging, trampling, and perhaps intentional re-cycling of some of its materials (Barbetti 1986); these processes (or the possibility of these processes having occurred) greatly complicate the identification of conclusive proof of anthropogenic fire-use. What perhaps makes the direct archaeological study of Mode 1 fire-use (especially how and when it first appeared) most highly problematic is that it is not until fire is taken out of its natural context and placed within anthropomorphic contexts (e.g. hearths) that it becomes archaeologically visible. Mode 2 and Mode 3 may involve the use of hearths, while Mode 1 is essentially the direct utilisation of Wildfire Package affordances without the requirement of capturing or controlling fire.

Therefore a considerable lack of clarity exists regarding both the timing and the reasons behind the initial uptake of anthropogenic fire-use (Roebroeks and Villa 2011, Wrangham 2009, Gowlett 2016). Unless other direct evidence of hominin activity was created and preserved (e.g. cut marked bones, lithic debitage or other lithic evidence) the archaeological record will not distinguish between wildfires opportunistically utilised by ancient hominins and wildfires not utilised by hominins. Even if evidence was found, how can researchers involved be absolutely sure the fire did not pass over a site previously utilised by hominins? To date direct clear incontrovertible evidence of Late Pliocene/ Early Pleistocene hominin fire-use has yet to be located, yet many have tried citing different lines of potential evidence. Bellomo (1993) suggested that the temperature a fire burns at was indicative of its nature (i.e. natural anthropogenically controlled). The temperature of burning can be increasingly accurately identified through scientific methodologies such as magnetic and spectrographic analyses according to Goldberg et al. (2017) and Aldeias (2017) (who in their respective papers summarise the types of data and analyses that can be used as well as quantifying how actual burned residues can be differentiated from naturally occurring sediments that may potentially mimic them). However contrary to this approach research conducted by Gowlett and colleagues, in synchrony with research reported here (Appendix A), shows that the use of maximum burning temperatures to identify anthropogenic fires should not be considered robust or high quality evidence (Gowlett et al. 2017). In reality the maximum temperature attained by a fire appears relatable to the complex interplay between environmental conditions (e.g. moisture content and wind speeds), fuel type and loads. Animal dung such as cattle or buffalo dung was personally observed burning at temperatures significantly greater than 1000^{O}C (measurements taken with thermo-couples attached to long heat-resistant leads) which is inconsistent with Bellomo's (1993) suggestion that wildfire burns at between 400-700^{O}C.

Identifying ancient evidence of hominin fire-use

The evidence for fire-use in Africa before 1Ma has been repeatedly identified as inconclusive (e.g. Isaac 1982) or relying on too much supposition (e.g. Clark and Harris 1985). New more complex methodologies such as Raman Microspectroscopy, Fourier transform infrared spectroscopy, Electron Energy Loss Spectroscopy, Thermoluminescence and Electron Spin Resonance measurements can all be used to indicate if materials were heated or burnt in antiquity (Schmidt et al. 2002) but will not necessarily be able to help researchers distinguish whether a fire was utilised by hominins or not without direct evidence of hominin activity (e.g. burnt microartifacts and/or butchered bones in distinctive distribution patterns). To identify ancient evidence of hominin fire the most common methodology used is a two step process (Barbetti 1986, Bellomo 1993, Bellomo 1994) whereby evidence must firstly show that fire was categorically present at the site, and secondly that it was directly associated with hominin activity. This essentially leaves researchers with a simple yes/no dichotomy as to the presence of fire at a site which does not take into account the fact that the earliest hominin fire-use must have been Mode 1 and therefore would have been conducted in interaction with wildfire. Archaeology's working hypothesis that something will not be taken to exist unless it can be proven beyond all reasonable doubt is not always the most appropriate stance to take when the archaeological record can be shown to be of both low quality and extremely poor resolution (as per Gowlett et al. 2012).

It seems that the scarcer or older the evidence, the more easily it can be dismissed. The evidence for anthropogenic fire-use before 1Ma has perhaps too easily been discounted by simply asking: 'How do we know for sure this is not simply evidence of wildfire?' Of course this ignores the self-evident fact that the earliest hominin use of fire would have been the utilisation and exploitation of simple Wildfire Package affordances; this may have been the case for millions of years before more complex hominin fire control emerged. While fire has been previously cited as a complex tool (Barham 2013) it is also a simple tool with a myriad of uses that will not leave archaeological traces. Alternative evidence and methodologies are therefore required to generate data to support early fire theories. This is in addition to adapting common paradigms within the research community so as to create a better-resolved view of the hominin evolutionary path. Chapter 5 and 6 of this study contains the methodology, data and results of one recent study undertaken to this end.

Archaeologists and other researchers have long sought to identify hard evidence to support hominin fire theories. Many potential sites with 'evidence' of ancient hominin fire-use have been identified, published, criticised and fiercely debated; however in this study archaeological evidence of ancient hominin fire-use is not reviewed in any depth (as this would require at least an entire chapter - but for a good recent review see Attwell et al. 2015 or Gowlett 2016) as they are not entirely relevant to this thesis. However here a table (Table 2.1) compiled by Cornelio et al. (2016) is presented which clearly shows the lack of association between what they class as very weak evidence (VWE) and irrefutable evidence of hominin activity (e.g. knapping). In addition a brief resume is presented of three East African sites (two Kenyan and one Ethiopian) that dating has identified as being ‘roughly contemporaneous. No older African evidence has been posited than these three sites. They are highlighted in this study as it appears somewhat strange that a range of different published evidence of hominin fire-use has been proposed from a relatively small geographical area (Fig. 2.2) all dated to a 0.2Ma period from 1.5Ma-1.3Ma. This is just the kind of pattern to be expected if a new behavioural adaptation had emerged, become ‘fixed’ in a population as a ‘regional tradition’ or cultural capacity and then gradually over a long period of time became more complex and eventually archaeologically visible. It is suggested here that this *might* be evidence of a ‘cultural blooming’ of hominin-fire behaviour; it is not suggested here that this is evidence of the earliest hominin-fire behaviour.

The three sites are: Koobi Fora (site FxJj20) at East Turkana, Kenya (an area renowned for exhibiting extensive hominin activities [Isaac and Harris 1997]) dated to between 1.6Ma (Bellomo 1994) and 1.5Ma (Clark and Harris 1985); site GnJi 1/6E in the Chemoigut Formation at Chesowanja near Lake Baringo, Kenya (Gowlett 2016); and, Gadeb 8E, an Acheulian site in the Upper Webi-Shebelle region of Ethiopia (Fig: 2.2). A range of different evidences has been excavated and examined from these three African sites: FxJj20 preserves burned sediments in a similar pattern to that produced by hearths (Bellomo and Kean 1997), and some stone artefacts which had been thermally altered. Material was excavated in association with a fragmentary fossilised bone assemblage including a *Paranthropus* (*Australopithecus*) *boisei* mandible (KNMER 3230) (Clark and Harris 1985, Bellomo and

Kean 1997). Furthermore evidence of phytolith heterogeneity suggests this is not evidence of a wildfire burnt tree (Alperson-Afil and Goren-Inbar 2010). Through a broad range of analyses Bellomo (1994) convinced himself that the evidence from site FxJj20 was so good that specific hominin behaviours identified (e.g. protection from predators) and ruled out (e.g. hunting or vegetation clearing).

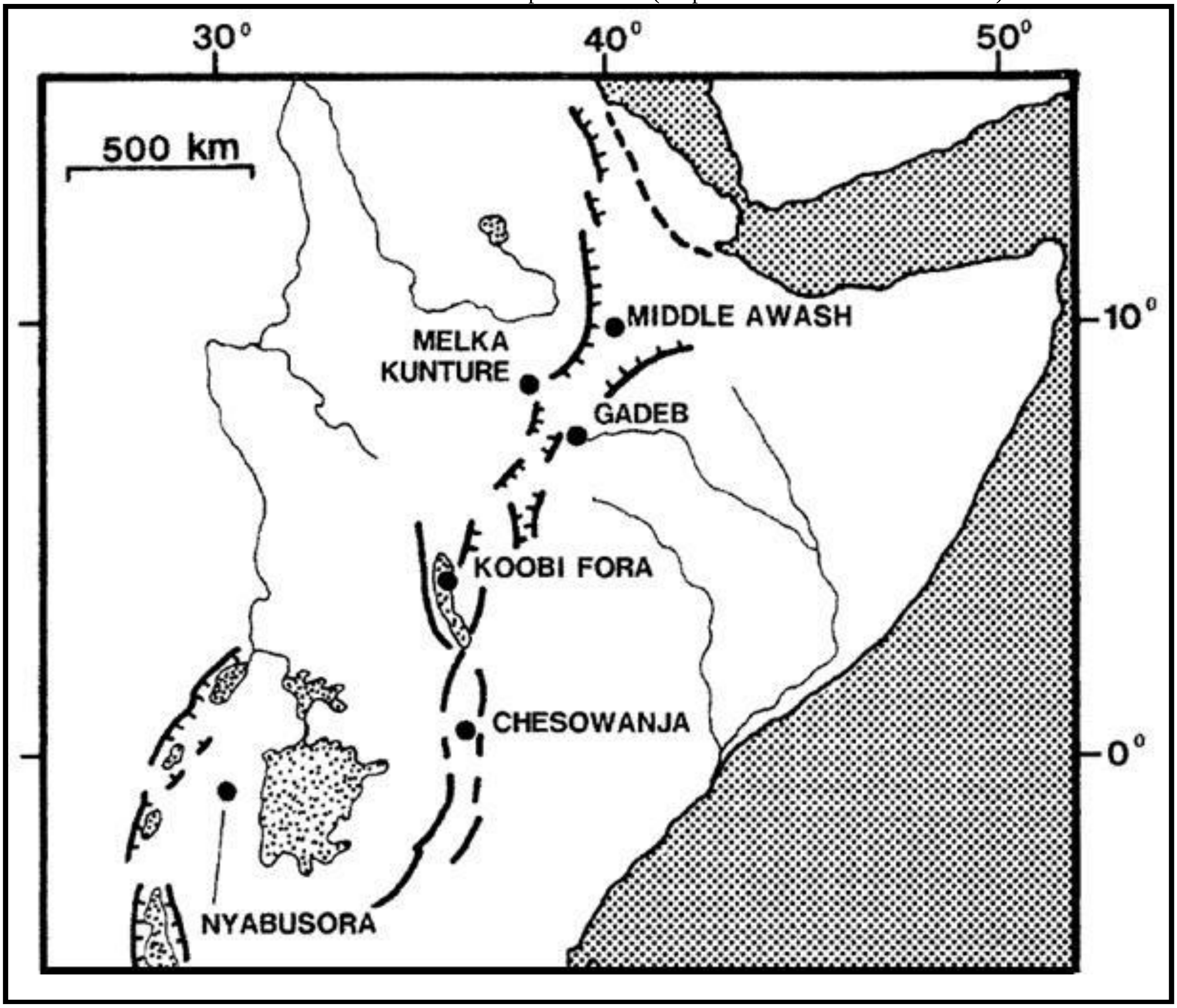
Archeological site	Date (MYA)	Country	Kind of evidence					Association	Classification	Reference
Yuanmou	1,7	China	C	BB?				None	VWE	James, 198
Koobi Fora	1,55	Kenya	BL?					None	VWE	James, 198
Koobi Fora	1,4	Kenya	RA	BL?				None	VWE	James, 198
Chesowanja	1,4	Kenya	BC					None	VWE	James, 198
Swartkrans	1,2	South Africa		BB				not clear	WE	Brain and S
Wonderwerk Cave	1	South Africa	A	BB	T			not clear	WE	Berna et al.
Gesher Benot Yaakov	0,79	Israel	H	T				Clear	SE	Alperson-A
Zhoukoudian	0,5	China	BD	BL				None	VWE	Weiner et al
Atapuerca	0,6	Spain	H	T	HB			Clear	SE	Arsuaga et
Zhoukoudian	0,45	China	H	BB	BF			not clear	WE	Wu, 1999
Schöningen	0,4	Germany	A	C	FHW	BF		clear	SE	Thieme, 19
Qesem Cave	0,38	Israel	H	BB	BF	HB	T	clear	SE	Karkanas e
Bajondillo	0,15	Spain	H	BF	BB	HB	T	clear	SE	Cortés-San
Bolomar	0,13	Spain	H	BF	T	HB		clear	SE	Blasco, 200

SE, strong evidence; WE, weak evidence; VWE, very weak evidence; NE, non-existent evidence; FHW, fire-hardened wood; BB, burned bones; BS, burned shells; fire-cracked rock; BL, burned lithics; H, hearth; C, charcoal; BD, burned deposit; BC, baked clay; A, ashes; RA, reddened area; HB, human bones; T, tools.

Table 2.1: Archaeological evidence of fire use and control by ancient hominins (from Cornelio et al. 2016)

The site of Chesowanja (dated to ~1.4 ± 0.07 Ma by K-Ar Isotopic analysis - Gowlett et al. 1981) produced a few large clasts of baked clay (Gowlett et al. 1981) that appeared to initially provide robust evidence as it was hypothesised that natural fire would not produce the temperatures required to generate this material. However, it could not be proved that this material did not come from an adjacent (but lost) natural burning feature (e.g. a tree stump covered by a clay termite mound could have acted as a kind of 'natural kiln'), as proposed by (amongst others) Isaac (1982) and (Clark and Harris 1985), even though the clasts are directly associated with numerous other evidence such as lithic tools and faunal remains (Gowlett 2016).

Figure 2.2: A map showing the location of East African archaeological sites from which the most credible evidence has so far been excavated for hominin fire-use prior to 1Ma (adapted from Clark and Harris 1985)



Excavations at Gadeb 8E unearthed *in-situ* stone accumulations showing differential dark grey and red discolouration (Barbetti 1986) which then underwent palaeomagnetic analysis. However results were weakened by excavation errors; some lithic artefacts may have initially been in a hearth-like formation but the significance of the find was only realised late on in the excavation (Clark and Harris 1985, James et al. 1989). Acknowledging that no archaeological evidence exists for hominin fire interactions older than from the three sites mentioned should this pattern be viewed as the first archaeologically visible shoots sprouting from a deep root? Like any shoot growing from rootstock there is no guarantee of success; indeed if this was anthropogenic fire-use there would of course be no evidence to say that the communities deploying it either thrived because of it or even survived to pass it on to future generations. Continuing to use a 'rootstock' analogy, it can be expected that shoots will sprout in different places.

Mode 1 fire - definition and terminologies

In this study the terminologies used when discussing the earliest hominin fire-use are often slightly different to prevailing norms. Definitions seem especially important when attempting to say something new. This may be particularly so when current definitions may have been constructed under no longer prevailing paradigms or under paradigms that run contra to the reasoning of a model or theory; hence the slightly different definition of 'early fire' used in this study. The Mode 1 concept also perhaps could benefit from some dissection and analysis.

Gowlett (2010) suggested that the three stage model is purely to aid a broad analysis, and in the model provided by Gowlett (2010) many things are clear; e.g. it is very clear that any fire that has been deliberately anthropogenically ignited is not Mode 1. However the Mode 2 and Mode 3 fire-use concepts are perhaps easier to delineate than Mode 1. A clear distinction between Mode 2 and Mode 3 exists; Mode 3 is 'ignition at will', Mode 2 does not involve anthropogenic ignition. As well as indicating a different kind of use of fire to Mode 1, Mode 2 denotes a greater general control of fire. Another clear distinction between Modes 1 and 2 is that there is considerable two-way exchange between Mode 2 fire and natural fire which can be modelled as both deliberate (e.g. fire-stick farming [Jones 1969]) and non-deliberate (e.g. when a conserved fire spreads out of control) but Mode 1 fire is not thought of s a two-way process (Fig. 2.2).

Gowlett (2010: P356) defined Mode 1 as: "*opportunistic use – searching for fire events, coupled with exploitation of their immediate opportunities; available to hominins living in savannahs and temperate forests*". It is noted here that opportunistic fire-use should not be viewed as unique to hominins; it is the only kind of fire-use practiced by animals other than humans. Primates, birds and a broad range of predators have been observed opportunistically taking advantage of wild and anthropogenic fires (e.g. hunting insects fleeing from smoke and flames, or searching for charcoal as medicine [Struhsaker et al. 1997, Bouwman and Hoffman 2007, Herzog et al. 2016]). However, hominins alone have built upon opportunistic fire-use to have now so firmly placed fire at the heart of their niche. In this study it is not simply the opportunistic use of fire that is of interest but specifically the idea that adaptive selective pay-offs led to the deliberate and preferential seeking out of these opportunities.

Gowlett's (2010) definition does raise some important questions. Does actual fire (i.e. flames, heat and/or smoke) have to be involved? For example, is chasing wounded prey fleeing a wildfire classifiable as Mode 1 even if no direct contact occurs between hominins and fire? Should preferential grazing on young new plant growth after a wildfire has consumed the old tougher less nutritious and digestible plant stock be rightfully classed as Mode 1 (even though this may be days, weeks or months post-burn)? Does the use of a recently burnt open area for a nursery or thoroughfare class as Mode 1? When approaching these types of questions, and by using the term Mode 1 (as defined by Gowlett 2010), it appears that a less clear distinction is made between Mode 1 and 'the pre-Mode 1 condition' than between Mode 1 and Mode 2. Without wanting to overanalyse the term, Mode 1 (as per Gowlett 2010), does not quite fit with some aspects of FAF theory (Chapter 4) so a slight adjustment to the definition is perhaps required to enable researchers to comprehend exploitation of a variable combination of Wildfire Package affordances (some immediate and some delayed). One reason for this adjustment is the clear acknowledgment that fire can directly persist on the landscape for some time. Due to topographical considerations and the insulative effects of clay and other regoliths a tree's rootball may burn and remain smouldering but very hot for weeks after a wildfire has passed through an area of shrub or woodland. During Ph.D fieldwork at the Soetoring Nature Reserve in South Africa in 2012 a temperature in excess of 700^{O}C was recorded within smouldering roots 15 days after wildfire had passed through; this affordance is exploitable in many ways (e.g. heating, cooking and smoke production).

Non-immediate Wildfire Package affordances

As well as the immediate physical effects of wildfire, such as a clearer field of view, a number of longer-term landscape-scale physical impacts occur that are only of interest to researchers who are able to view wildfire holistically as a package of short and long term benefits (rather than researchers looking purely at the immediate opportunistic foraging benefits). A number of benefits of foraging on wild fire sites have been identified that only occur some considerable time after burning (Yarnell et al. 2007); for example when fire, acting like a generalist herbivore, removes dead biomass initiating a flush of highly nutritious new growth (Parr and Chown 2003). Increased herbivore densities have been observed on wildfire burnt environments some time post-burn (e.g. 2-3 months depending on biotic and abiotic factors) resulting from grazers foraging for young nutritious shoots (Van de Vijver et al. 1999, Lindenmeyer et al.2008, Green et al. 2015) which are more easily digestible and more nutritious than older material (Wilsey 1996, Tomor and Owen Smith 2002) and leads to greater mass gains compared to feeding on unburned patches (Van de Vijver et al. 1999).

Wildfire resets plant successions, enabling new niches to be created, and physically and chemically reformats and redistributes minerals and nutrients around the landscape. Post-fire above-ground plant regrowth can have short-lived significantly higher macronutrient concentrations than unburned vegetation (Van de Vijver et al. 1999)[4] which is very attractive to certain groups of herbivores (e.g. Topi) (Green et al. 2015). Additionally, higher levels of species diversity (plants, vertebrates and invertebrates) can also be recorded after a wildfire; due to ecosystem disturbance, pioneer species invade into what were previously stable niches (Connel 1978). If patterns of higher patch biodiversity were visible to, and preferentially exploited by, early members of *Homo* or their antecedents, as they frequently are by modern hunter-gatherers (e.g. personal observations on the Hadza of Lake Eyasi [2005] and the Wana people of Morowali [1996]), then in this study this kind of relationship with Wildfire Package affordances is viewed as being covered by the 'Mode 1' concept.

Therefore in this study 'opportunistic' fire-use is viewed as possible after fire has died down and after any immediate significant danger of death or injury due to smoke and flames has subsided as some Wildfire Package affordances can still be opportunistically exploited. In this study the Mode 1 definition is slightly adjusted so that '*immediate opportunities*' becomes simply '*opportunities*'. However this adjustment should not be seen as overly significant because, to reiterate what Gowlett (2010) suggested, the three stage model is there purely to aid a broad analysis. When delving into the minutiae any definition used may confuse, constrain and restrict rather than aid. Perhaps the most important information any reader can have gleaned from this section is not regarding the specific definitions of the terminologies used, but instead what the themes covered in this study are, and are not. In the interest of clarity the term Mode 1 is used as infrequently as possible in this study.

[4] Van de Vijver et al. (1999) observed that one month after burning, post-fire plant regrowth had 53% higher nitrogen, 40% higher phosphorous, 23% higher potassium, 64% higher calcium, and 73% higher magnesium concentrations; but after three months nutrient concentrations had declined to the levels within control plots.

Should the earliest Mode 1 hominin fire-use be viewed as an African phenomenon?

Opportunities for opportunistic fire-use were definitely available to Plio-Pleistocene hominins living in savannahs and temperate forests (as per Burton 2009 and Gowlett 2010). Wildfires are much more frequent in savannah/bushland environments than temperate forests; this is especially so in modern day Southern Africa where fires are largely grass-fuelled surface fires (Archibald et al. 2010). It can be surmised that the more numerous the opportunities to benefit from Wildfire Package affordances then the stronger adaptive the selective pay-offs and forces will be. Therefore it appears most parsimonious that the initial uptake of Mode 1 fire-use would occur in a savannah/bushland environment rather than any other ecotype due to its greater prevalence. This is not to say that the initial uptake of Mode 1 must necessarily have taken place in Africa. Savannah/bushland habitat is available in other areas colonised by *Homo* after ~1.8Ma (e.g. the Indian subcontinent). However, it should be noted that, as well as the use of fire having the capacity to increase a species eurytopy thus facilitating migration (Atwell et al. 2015); relative to other continents Africa has the most wildfire. While acknowledging that extensive parallelism is well-documented among higher primates (White et al. 2015) the most parsimonious conclusion reached in this study is that Mode 1 fire-use, or at the very least a more close relationship with fire that includes diminished fear of fire (i.e. a deep root) would occur prior to dispersal from Africa.

However this may be a contentious point, especially for those researchers who believe in a recent uptake of fire-use. Roebroeks and Villa, prominent early-fire deniers who took a strong stance against the very foundations of early fire theories in a seminal 2011 paper nonetheless do not deny; '*the possibility of occasional and opportunistic use of fire in earlier periods*'. They further clearly state that (Roebroeks and Villa 2011; P5212); '*living in 'fire-rich' environments may have triggered the repeated opportunistic use of natural fires in early* *stages of hominin evolution, but such use did not create an archeologically visible pattern*'. As the FAF hypothesis is focused on these very early simple interactions it appears that even the most high profile 'early-fire deniers' can agree with core tenets of FAF even if they still view hominin fire-use as a much more recent adaptation. The idea that hominin fire interactions started before hominins left Africa for the first time is at the forefront of the approach taken in this study. In this study a deep root is hypothesised and mobilised (as per Burton 2009) and is elaborated on in detail later in this chapter.

Fire Intensity

A point already clearly made in this study is that any robust attempt to construct a resilient case for Mode 1 opportunistic fire-use concomitant with (or predating) *Homo* requires assessment of a number of strands of evidence from many different perspectives. It also requires acknowledging that each fire event can be very different due to a large number of biotic and abiotic factors. One of the key variables that can be used to differentiate different kinds of fire is the level of intensity created by a burn. Fire intensity can determine the nature of many of the impacts of fire on landscapes (Govender et al. 2006) and also the nature of each fire's package of effects and affordances. Fire intensity is a very important variable as it impacts how, and for how long, wildfire manifests on the landscape. Many different factors (e.g. day/night burn and moisture content) can influence fire intensity even considering that factors such as available fuel loads remain constant (Govender et al. 2006). Fire intensity depends on the amount of fuel consumed and the ambient weather conditions under which fires burn (Govender et al. 2006); both of these variables affect the rate of spread, a key factor for determining the individual characteristics of a wildfire. From an ancient hominin perspective, being able to quantify, recognise and predict the intensity of a fire can determine the amount of danger present and the appropriate strategy to deploy (e.g. exercise caution, leave or hunt/scavenge).

An evolutionary psychology framework

The theoretical foundation for these studies derives from the acknowledgement that, according to general evolutionary theory (Han 2007), natural selection favours individuals who were motivated to explore and utilise environments likely to afford the necessities of life, and to avoid environments with poorer resources or those that pose higher risks (Orians and Heerwagen 1992). Certain fundamentals aspects of natural selection (in this case specifically 'Habitat Selection Theory' [Kaplan and Kaplan 1989]) depend on the fact that, as habitat selection is closely related to the successful survival, reproduction, and well-being of a community or species, selecting appropriate settings to inhabit is an essential and necessary activity for animals (Kaplan 1987, Kaplan and Kaplan 1989, Orians and Heerwagen, 1992).

This study incorporates and evaluates ideas from both evolutionary psychology and behavioural ecology. Evolutionary psychology is based on the idea that, just like a vital organ, cognition has functional structure with a genetic basis evolved by natural selection (Barrett et al. 2002). The cognitive functional structure of a species solves important problems of survival and reproduction and is universally shared amongst a species (Workman and Reader 2004). Evolutionary psychology views human cognition as the product of a universal set of evolved psychological adaptations created to deal with problems commonly encountered in ancestral environments (Confer et al. 2010). Evolutionary psychology views natural selection as a process in which a successful phenotypic design feature drives its own spread through a population.

In contrast behavioural ecology focuses on the idea that certain traits and behaviours can have adaptive significance, which can be selected for by natural selection. Ideas from both of these academic disciplines are important for successfully tying together this research on perceptions and attitudes to fire in modern populations with a model that attempts to explain the timing and nature of the initial appearance of deliberate opportunistic hominin fire-use. This approach seems well suited to be able to coherently explain the universal use of fire by modern humans. This is especially true when ‘non-referential modelling’, which attempts to reconstruct hypothetical ancestral behaviour using rules derived from evolutionary biology and behavioural ecology, is incorporated into the methodological design (Whiten et al. 2010, Duda and Zrzavy 2013); as is the case in this study.

Evolutionary psychology adopts an understanding of the mind based on the computational theory of mind and views the brain as a naturally constructed computational system whose function is to solve adaptive information-processing problems (such as risk interpretation) (Workman and Reader 2004). Neural circuitry would have been ‘selected for’ that was efficient at solving our antecedents’ daily problems such as feeding and risk management (Barrett et al. 2002). Evolutionary psychology views mental processes, such as a fear response, as a computational operation where inputs of perceptional data like a lion’s roar induces an output in the form of a behavioural response e.g. increased vigilance investments preparation to fight/flee (Workman and Reader 2004). Paleoanthropologists are well aware that natural selection slowly sculpted the hominin brain; evolutionary psychologists view natural selection as a complexity of feedback processes that selects from alternative designs on the basis of adaptive pay-offs (Confer et al. 2010). Hominin psychology consists of many highly specialised mechanisms which when combined produce observable behaviour (Mobbs et al. 2015). Behaviours or traits that are universal constants (e.g. tool use, fire) should be viewed as excellent candidates for evolutionary adaptations. However, this is not to say that these traits can necessarily be retro-engineered to recreate ancient psychological states.

It is well recognised that certain landscapes have had long standing selective value for hominins (Finlayson et al. 2011). The proposition that to properly understand the functions of the brain, one must understand the properties of the environment in which the brain evolved is very pertinent to this study (as per Christakos 2011). The evolutionary environment is often referred to as the ***environment of evolutionary adaptedness*** (Workman and Reader 2004); a statistical composition of selection pressures rather than an actual physical environment (although in the case of hominins this is usually presumed to be some of the myriad of different African habitats). This is an idea that fits neatly with the concept of mental landscapes (e.g. Landscapes of Fear) which are mapped by calculations of risk, danger and benefit; Landscapes of Fear (LOFs) form a central and important part of this study (discussed in detail in Chapter 4).

The environment of evolutionary adaptedness pertinent to the earliest hominin fire interactions should be viewed as not only wildfire impacted environments but also the sum total of all the landscapes occupied and used by those ancient hominins. This Plio-Pleistocene environment of evolutionary adaptedness can be viewed as significantly different from anything we have today even for the most remote and 'traditional' hunter-gatherer communities. Despite this realisation, often researchers still study hunter-gatherer societies for clues as to how environments of evolutionary adaptedness were exploited (e.g. Marlowe and Berbesque 2009, Wiessner 2014); this approach underpins this study's cross-cultural data collection survey (Chapters 5 and 6).

Cognitive mechanisms that exist because they solved problems efficiently in the past will not necessarily generate adaptive behaviour in the present, but they may still be present within the neural circuitry of that individual. Evolutionary psychology proposes that the majority of modern human psychological mechanisms are adapted to deal with problems frequently encountered in ancient (e.g. Pliocene) environments; some of which are behavioural relics (Workman and Reader 2004, Mobbs et al. 2015). Modern psychological relationships with fire should therefore be able to provide insights to those trying to study and model ancestral strategies and behaviours. Previous evolutionary psychological studies have been attacked due to the significant mismatch viewed as existing between modern humans' evolved fear-learning psychology and the nature of modern environments (Confer et al. 2010). However in this study it is precisely the nature of this mismatch that is of specific interest.

At the forefront of this study is the idea that the earliest repetitive deliberate opportunistic interactions between hominins and fire are exaptive (see chapter 3); evolutionary psychology appears well suited to dealing with the concept of exaptation (Workman and Reader 2004). If a novel behaviour or trait emerges that is a better adaptive strategy than a pre-existing strategy then this will then be selected for (initially culturally) as it affords new beneficial opportunities to improve biological fitness (e.g. the ability to ignite fire at will and cook food/make hafted tools as an obligate learned behaviour would then take over from a pre-existing fire-use, altering evolutionary trajectories); this scenario would result in the ways that modern humans use fire being different from ancient hominin fire relationships. In this scenario if the original relationship of fire was, for example, to use a wildfire burnt environment as a safe social space and refuge from predators, this may no longer be relevant today. Behavioural relics however may exist and be identifiable within the thinking of modern humans as vestiges of this earlier, now redundant, behaviour which can be tested for and identified (ideally through the analysis of large cross-cultural datasets).

As mentioned in Chapter 1 evolutionary psychology has previously generated substantial controversy and criticism (Plotkin 2004, Tooby et al. 2005, Confer et al. 2010, Barret et al. 2014) particularly as issues exist around surrounding the testability of evolutionary hypotheses. Additionally evolutionary psychology struggles to cope with the fact that alternatives exist to some of the cognitive assumptions frequently employed in evolutionary psychology (e.g. massive modularity) (Plotkin 2004). The human brain appears highly flexible with many alternative pathways available to achieve the same (or very similar) behaviours or results (Sherwood et al. 2008). If the assumption is made that specific neurological architecture is inherited due to past selection pressures and adaptive selective behaviours (an assumption made within the Fear and Flames hypothesis) then this acknowledgment will inevitably weaken the underlying theoretical foundations. However here this is countered by the idea that brain modularity that produces similar results due to a number of different, possibly parallel, systems or neural pathways may in fact be guided by deep underlying neural hardware (possibly deep within the limbic system, a sytem which supports emotion and behaviour [as per Sherwood et al. 2008]). Additionally evolutionary psychology requires making some assumptions that are relatively unsupported (including the specific nature of ancient hominin environment[s] of evolutionary adaptation) (Tooby et al. 2005). Increasing the resolution of the archaeological record by developing and integrating innovative research from a number of methodologies will help researchers get a more detailed idea of ancient hominin environment[s] of evolutionary adaptation. This will take time and will be a continuous process.

However, like all other sciences attempting to illuminate ancient hominin behaviours adaptations and lifeways, evolutionary psychology progresses through the creation and testing of hypotheses. It is believed that by acknowledging the inherent weaknesses of this approach, instead of discrediting the approach, in the absence of a 100% robust alternative (and to date none exist to approach this topic) the evolutionary psychological approach manages to retain its relevance precisely because so much about human behaviour is explainable by utilising it. Perhaps of greater long-term concern to the broader field of evolutionary psychology is that it also appears to struggle and deal with a rapidly developing understanding of epigenetics; probably partly because this field is so new and often relatively misunderstood. To counter this argument it should be noted that the human niche is changing now at a faster pace than ever before (e.g. the pace of technological development); therefore epigentical change can also be assumed to be at a greatly accelerated rate now than during much of hominin history.

Evidence for behavioural relics in modern humans

The restorative power of nature is well recognised within the scientific community (e.g. Kaplan and Kaplan 1989, Bratman et al. 2012). Certain natural environments give humans a sense of peace and safety (Kaplan and Kaplan 1989, Ulrich 1993, Kaplan 1995). Affective reactions to environments may happen at a preconscious level as conscious processes are not necessary or required to produce emotion (Ulrich 1983, Bratman et al. 2012). A primary function of the mammal brain is to generate behaviour appropriate to external (environmental) conditions received from multi-sensory stimuli. Hominin neurological circuits are designed to generate actions (behaviours) in response to environmental information and are designed to solve adaptive problems (Mobbs et al. 2015); the evolutionary psychology perspective is that adaptive problems are the only kind of problems that natural selection can act on (Workman and Reader 2004). The sense of peace and safety provided by certain natural environments is therefore related to relationships and behaviours from our evolutionary past and should be viewed as solutions to adaptive problems (Workman and Reader 2014). A sense of peace and safety will allow vigilance levels to decrease and an organism to relax enabling more resources to be spent on other activities such as social time or rest and recuperation.

Adaptive problems have two defining characteristics. First, they will have cropped up again and again during a species evolutionary history; and secondly, solutions to these problems must affect the reproduction of individual organisms (Workman and Reader 2014). An effect must be had on the number of offspring produced because differential reproduction (and not survival per se) is the engine that drives natural selection (Confer et al. 2010). If the sense of peace and safety provided by certain natural environments were misplaced (i.e. that environment was not peaceful and safe) then this may have a negative effect on the number of offspring produced or surviving. Using evolutionary psychological principles natural selection will take a long time to design a circuit of any complexity (Confer et al. 2010), although epigenetic processes (the mechanisms of which are currently very poorly understood) may significantly impact on these time frames. **In this study the view is taken that fire is deeply rooted in hominin evolutionary history** (an idea discussed in greater depth later in this chapter); **if hominin fire-use is deeply imbedded within the hominin brain and psyche a long time is thus afforded for neural circuitry to develop.** As behavioural relics have been previously recognised in the psychology and cognition of a number of different modern populations in a number of different (non-fire related) studies (Han 2007) the existence of behavioural relics relating to ancient fire-use strategies within modern humans psychology is eminently plausible.

Methodologies similar to those used later in this study have been deployed to approach topics such as the impacts of nature experience on human cognitive function and mental health (Bratman et al. 2012), precocious knowledge of anti-predator refuges (Coss and Moore 2002), and human relationships with aspects of the environment such as tree shapes (Sommer 1997, Lohr and Pearson-Mimms 2006, Han 2007). Research has shown that modern humans can exhibit aesthetic, emotional, and physiological responses to scenes and other sensory stimulations of natural landscapes (Lohr and Pearson-Mimms 2006). This doesn't necessarily mean that they are hardwired by evolution; however without breeding a generation of humans in a laboratory environment (which is most unlikely to garner ethical approval) and undertake a series of test on them this will be a difficult topic to approach.

Limitations of using ethological and primatological data

Throughout this dissertation ethological and primatological data is presented to support ideas, scenarios and theoretical positions; extinct animals can only be well understood by using modern animals to help interpret their structure, functioning and behaviour (as per Gamble et al. 2014). Rather than continuously repeating provisos about the inherent weaknesses of this strategy the limitations of this approach are here briefly highlighted and are taken to apply to all citations to 'personally observed' or previously published ethological and primatological data within this study. Ethology and primatology are disciplines that have been cited as being able to provide a good insight into the possible behavioural patterns of early hominins, and the evolution and development of early hominin culture (Mercader et al. 2002, 2007, Carvalho et al. 2008, Sayers and Lovejoy 2008, Haslam et al. 2009). By analysing the distribution of character states present in contemporary species within an established phylogeny, the principle of parsimony may be used to make reasonable inferences concerning the condition of extinct ancestral taxa (Johnson et al. 1984; Sherwood et al. 2008) (although it is again noted that extensive parallelism occurs among higher primates [White et al. 2015]).

In this study ethology is used as only one line of evidence and is supported by other observations and lines of evidence. Ethological evidence and observations are viewed as providing some solid foundations for research as long as it is recognised that one of the important factors to constantly remember when working in palaeoanthropology is that it is not necessarily what hominins did similarly to other primates that is important, but what was done differently (as per Sayers and Lovejoy 2008). Primatological and ethological data should only be used if it is clearly recognised that all living species are the product of their own evolutionary trajectory and cannot be considered true ancestral hominin analogues. While chimpanzees, by both homology and analogy, have been suggested to be the best available model for reconstructing the behavioural traits of hominin ancestors close to the LCA and the appearance of *Homo* (e.g. Sayers and Lovejoy 2008); this assertion can be opposed by researchers (e.g. Crompton 2016)who follow the tenet that chimpanzees are in fact much more highly derived from the LCA than *Homo*, are completely unlike other apes (which including humans are all selected for plasticity) and are in effect a lousy model for anything except themselves.

While acknowledging that chimpanzees may in fact be more derived from the ancestral state than *Homo*, due to the ~98% shared DNA (Bonnefille 2010) chimpanzees may provide important general insights for understanding ancient hominin strategies, adaptations and behaviours (Hernandez-Aguilar 2009, Pruetz and LaDuke 2010). For example, observations of wild chimpanzees interacting with fire should be accorded respect; indeed in their important observational paper Pruetz and Laduke (2010:1) make the specific point that studying chimpanzee behaviour enables '*human autapomorphies to be distinguished from hominoid synapomorphies*'. According to Sherwood et al. (2008: 427) when a character state is observed only in modern humans and not in any of the other extant great apes, then '*it is reasonable to conclude that the modern human condition is derived compared to the symplesiomorphic state seen in extant great apes*'.

Homo, early members of *Homo* and *Homo* antecedents

Due to the scattered and fragmentary African Late Pliocene and Early Pleistocene fossil record (the definition of Pleistocene follows the new terminology, with a strt date of 2.6Ma) questions of hominin phylogenetics and classification remain unresolved (Lordkipanidze et al. 2013). Therefore in this study rather than referring to specific species names, the terms 'early members of *Homo'* and '*Homo* antecedents' are preferred. In this study 'early members of *Homo'* are defined as all members of the genus *Homo* confidently dated to between 2.8Ma and 1.8Ma (the earliest evidence for *Homo* out of Africa). Defining '*Homo* antecedents' is a little more difficult.

A review of *Homo* antecedents should start with *Sahelanthropus tchadensis* (6-7Ma – Brunet et al. 2002) and *Orrorin tugenensis* (~6Ma – Senut et al. 2001) due to surmised evidence for aspects of bipedality (e.g. the nature of the *foramen magnum*), also present in *Ardipithecus Sp*. (see White et al. 2015 for a comprehensive recent review of this genus). However in this study interest in *Homo* antecedents really 'fires up' once strong archaeological evidence of terrestrial bipedality is evident, i.e. *Australopithecus* (White et al. 2015). Australopithecines are visible in the African fossil record from ~4.2Ma with gracile and robust species proliferating widely over Plio-Pleistocene landscapes (Aiello and Andrews 2000).

Species distinctions within *Homo* have limited value in this study because of the prevailing problem of distinguishing 'who did what'; this issue also applies to early archaeological stone industries. The earliest stages of the Fear and Flames hypothesis need not be specifically linked to an exact location or hominin group, because there are multiple possibilities. Full reviews of lumping/splitting (also termed a 'speciose' hominin taxonomy [Wood and Lonergan 2008: 355]) and comprehensive reviews of the australopiths and *Ardipithecus* respectively were provide by Andrews and Aiello 2000 and White et al. 2015. Researchers are fairly confident that *Homo* evolved from one of the many proposed different species of *Australopithecus* (Foley 1993) (although hybridisation and/or a 'within-Africa *Homo* multiregionalism theory' cannot yet be entirely ruled out); exactly which lineage(s) were involved is very much open to debate and is not of massive specific bearing to this study. The term *Homo* antecedents can refer to all of the lineages of hominin ancestors back to and including the Last Common Ancestor (LCA) of *Homo* and *Pan* but here the term mostly refers to 'pre-*Homo* terrestrially bipedal hominins' living in the period 4.2Ma-2.5Ma.

Beyond an outline review, the earlier hominins have limited direct relevance in this study because to date no high quality evidence of hominin fire-use has been excavated or identified that predates the earliest known out of Africa hominin migration. Nevertheless they provide broader context, and brief summary is given here of some key differences between some of the better known ancient hominins around in the 4Ma - 2 Ma time period. A number of different reviews of this material are available but here the work and terminologies of Bernard Wood is focussed upon (e.g. Wood and Collard 1999, Wood and Richmond 2000, Wood and Lonergan 2008, Robson and Wood 2008). Further perspectives are given in the work of researchers like Kaye Reed (e.g. Reed 1997, Villmoare et al. 2015, Robinson et al.

2017), Mark Maslin (e.g. Maslin et al. 2014) and Tim White and colleagues (e.g. White et al. 2005 and White et al. 2015)

Australopithecines, in the form of *Australopithecus anamensis,* appear at about 4.5Ma (Leakey et al. 1995), already with some features undisputably associated with bipedality (Wood and Richmond, Wood and Lonergan 2008) inhabiting mosaic habitats including bushland and gallery forest (Leakey et al. 1995). A slightly later species, *Australopithecus afarensis* (~4-3Ma), does not yet show increased brain size (relative to body mass) and the hind limbs are still much shorter than Pleistocene *Homo* (Wood and Lonergan 2008); however anatomical evidence for bipedality is complemented by indirect evidence such as the hominin footprint trails identified at Laetoli (Wood and Richmond 2000). With the exception of lower limb features related to bipedalism, *A. afarensis* had a generally apelike skeletal design and body shape (McHenry 1991, Wood and Richmond 2000), and, due to the retention of multiple primitive features, is viewed as lacking refined manual dexterity (Wood and Richmond 2000). Again mosaic palaeohabitats are inferred (White et al. 2015). *Homo habilis* however has clearly enlarged endocranial volume but 'there is little to distinguish the postcranial skeleton of *H. habilis* from that of *Australopithecus* and *Paranthropus* (Wood and Richmond 2000: 40).However adaptations in the hand indicate that *H. habilis* was capable of the level of manual dexterity required to manufacture and use tools (Wood and Richmond 2000, Wood and Lonergan 2008). Many of the earliest specimens of '*Homo'* show differing combinations of primitive and derived features showing the complexity of taxonomic differentiation at this time in hominin history.

What is not seen in the archaeological record is a clear and logical progression and transition into *Homo,* although Villmoare et al. 2015 report a very early *Homo* mandible from Ethiopia. For example megadont paranthropines are viewed as highly adapted and specialised to their environment (as opposed to *Homo* the perceived generalists [Grove 2011, Potts and Faith 2015]) and can be viewed as evolutionary dead-ends, although they do survive long enough to be comtemporaries of *Homo* for well over a million years. *Australopithecus Africanus*, one of the latest australopithecines to appear in the fossil record (~ 3Ma-2.4Ma) is suggested by Wood and Lonergan (2004: 359) to be '*probably more arboreal than other archaic hominin taxa*'; again showing the lack of a clear progression into the kinds of traits associated with the evidently terrestrial and bipedal *Homo* body plan.

Homo is one of five genera currently assigned to the tribe *Hominini,* but is not 'a good genus', due to a lack of an accepted definition (Wood and Collard 1999: 70). The appearance of *Homo* is associated with profound changes in life history, as well as body size and shape (Shultz et al. 2012). In many ways (e.g. dentition, limb proportions, morphology and diet) the *Homo* body plan is very different to the body plan of *Homo* antecedents so significant cognitive differences can also be expected along with the form of respective niches; it is argued in this study that this will be particularly true when it comes to exploitation of landscape and environmental affordances. The arrival of *Homo* appears to mark the first clear occasion hominids exist in areas of fairly open, arid grassland (Reed 1997); again showing clear differences between the niches of antecedent species.

While the construction and use of lithic technology is plausibly a key construct of the *Homo* niche, as *Homo's* first widely accepted appearance (classified solely on the basis of tooth morphology) in the fossil record is at ~ 2.8Ma (Villmoare et al. 2015), but if *Kenyanthropus* is classified as *Homo* (as per Cela-Conde and Ayala 2003) then ~3.2Ma; however both dates are later than the initial appearance of lithic (Lomekwian) technology suggesting lithic technology should not be viewed as a *Homo* autopomorphy. The first archaeological sighting of *Homo* appears synchronous with a previously described distinct episode of faunal change and species turnover identified in the Omo sequence (Bobe et al. 2002) when dominance by suids gives way to dominance by bovids; thus clearly showing the impact of distinct climatic and ecotypic changes on the makeup of local foodwebs. This study proposes that hominin exploitation of Wildfire Package affordances, in the form of the Fear and Flames (FAF) hypothesis, can be used to explain many archaeologically observed differences between early members of *Homo* and *Homo* antecedents (morphological and behavioural) and importantly is not contradicted by others (discussed in depth in Chapter 4).

The palaeoecology of members of early *Homo*

Early members of *Homo* were undoubtedly omnivorous generalists whose niche incorporated mosaic habitats, of which savannah and bushland/grassland biomes (and therefore wildfire) were key constructs (Attwell et al. 2015). Early members of *Homo* are conspicuous for their significantly expanded niche (Bar-Yosef and Belmaker 2011, Kahlke et al. 2011) observed by 'out of Africa migrations' and archaeological sites identified within a number of very different palaeoenvironmental contexts (Rolland 2010, Finlayson et al. 2011). The survival and evolutionary history of early members of *Homo* shows that through innovative adaptive behaviours and tool-use they were able to effectively exploit and expand their niches. The ability of early members of *Homo* to migrate out of Africa at a time when there was a generally low rate of faunal exchange between Africa and Asia (Geraads 2010) is suggestive of a significantly enhanced degree of eurytopy and heightened awareness of landscape affordances (Kahlke et al. 2011). All of these factors may be relevant to fire knowledge.

At about 2Ma the genus *Homo* is known to have inhabited mosaic habitats in East and Southern Africa (Plummer et al. 2009, Finlayson et al. 2011, Anton 2012). By about 1.8Ma early members of *Homo* had dispersed broadly and by at least 1.3Ma were present in the

Palaearctic (Finlayson et al. 2011). Some researchers have suggested that the colonisation of higher latitude environments, such as the European Palaearctic where even during full interglacials the challenges of marked seasonality and cold winters must have been addressed (Hosfield 2016) (temperatures would have dropped below freezing at night and potentially during the daytime for long periods of time), was tied to the use of fire.

Due to the significantly greater prevalence of wildfire in equatorial regions (Africa in particular) the most parsimonious explanation would be that the acquisition of initial fire-use adaptations (including complex multi-faceted exploitation of Wildfire Package affordances) predates migration to northerly latitudes. Evidence from ‘stones and bones’ documents the rapid spread of early members of *Homo* into Eurasia (e.g. Georgia, Pakistan, China and Java) the Palaearctic and Northern latitudes (e.g. the Apennine Peninsula and France between 1.7 and 1.3 Ma [Carrion et al. 2011] arriving as far north as the UK by ~0.9Ma [Parfitt et al. 2010]). While conclusive evidence of hominin Wildfire Package exploitation at this time is lacking, it is proposed here that (as per Burton 2009) the ability and desire to exploit Wildfire Package affordances was an integral part of the toolkit of early members of *Homo*.

Homo arose during a time of heightened climatic variability (Potts and Faith 2015) which was either contiguous with, or a driver of, increased developmental and behavioural plasticity. Improved dietary quality and decreased extrinsic mortality (possibly in the form of reduced predation pressure) are viewed as important factors in the emergence of *Homo* (Aiello and Key 2002; Anton et al. 2002; Anton 2012), which coincides with a marked increase in seasonal variation in climatic and environmental conditions (Potts and Faith 2015); obvious selective pressures (Foley 1993, Grove 2011, Grove 2012). Increased levels of seasonality would have had a direct and significant impact on hominin behaviour especially in terms of foraging strategies. If it is accepted that: i) not all seasonal environments present the same adaptive problems; and ii) there was no single hominin strategy to deal with environmental change; then variability helps to account for the (apparently) rapid adaptive radiation visible in the African hominin fossil record between 3Ma and 1Ma (Foley 1993).

Early members of *Homo* have been modelled to have developed and deployed a 'human-like' foraging strategy (Leonard and Robertson 1992, Ungar et al. 2006), which requires an increase in total energy expenditure due to its more energy intensive nature (relative to the strategies of other primates), compensated for by an increase in dietary quality (Foley 2001, Ungar et al. 2006). For example, female early members of *Homo* (relative to Late Pliocene Australopiths), were calculated to have significantly greater total energy expenditure by ~80-85% (Steudel-Numbers 2006). Fear and Flames (FAF) (set out in detail in Chapter 4) states that the exploitation of Wildfire Package affordances would have helped increase total energy expenditure by allowing improvements to dietary quality and reductions to foraging costs such as vigilance investments. When available, exploitation of Wildfire Package affordances could have been a keystone resource optimisation strategy to fuelling the observed significantly greater total energy expenditure.

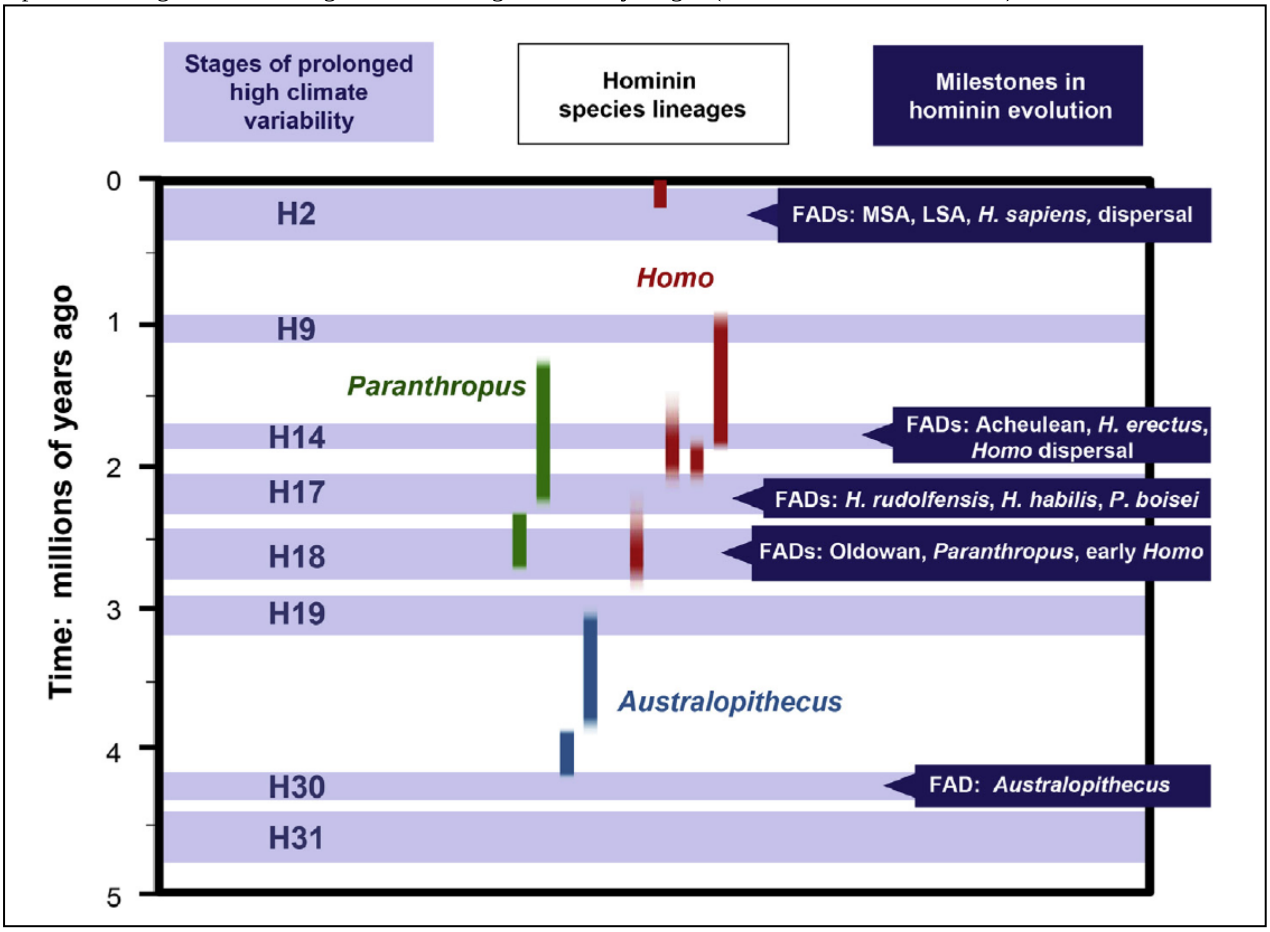
The importance of Variability Selection to the emergence of *Homo*

A reorganisation of global oceanic circulation systems driven by the final closing of the 'Central American Seaway' in the Late Pliocene (Coates et al. 2004) significantly impacted global climatic patterns, the final phase of which is synchronous with the current earliest evidence of *Homo*. The Variability Selection hypothesis, first applied to hominins by Potts (1998), suggests that increases in environmental fluctuation led to the evolution of complex, flexible behaviours with the ability to respond to novel and unpredictable adaptive settings being preferentially selected for (Potts 1998, Grove 2011). Variability selection says generally rather than specifically adapted species will thrive (Potts, 1998, Potts and Faith 2015). Variability selection would give rise to "*complex structures or behaviours that are designed to respond to novel and unpredictable adaptive settings*" (Potts 1998: 85) and therefore benefit species most able to react in flexible ways to changing environments, thus enabling them to eventually usurp more specialised species (Grove 2011).

The occupation of heterogeneous (patchy) environments and use of variable food sources favours a generalist strategy (Lovejoy 1981); the Wildfire Package provides heterogeneous environments and in this study is viewed as providing lots of scope for general adaptations. Innovation in the use of habitats, resources or space are suggested adaptive behavioural responses to changing environmental conditions (Shultz et al. 2012); e.g. increasing breadth of diet and foraging strategies allows the exploitation of resources across unpredictable mosaic habitats (Ungar et al. 2006), whereas cultural changes and the increasing use of tools opens up novel adaptive zones (Gamble et al. 2011). Potts and Faith (2015) predict that certain combinations of genes (coding and regulatory) that favour adaptability and their interactive effects are selected for during heightened variability in environmental conditions.

Late Pliocene cooling and drying trends forced hominins to move into novel habitats and alter their use of resources (Shultz et al. 2012). Palaeoenvironmental data has highlighted the period immediately preceding the emergence of *Homo* (~3.2Ma -2.8 Ma) (Fig. 2.3), when northern hemisphere glaciations was starting, as a time when versatilists with high levels of

Figure 2.3: Association between the eight longest eras of predicted high climate variability (shaded horizontal bars) and East African first/last appearance datums (FADs, LADs) of hominin genera and species, key technological innovations (earliest known appearances of the Oldowan, Acheulean, Middle Stone Age, Late Stone Age), and dispersals (early *Homo* and *H. sapiens*). The bottom and top of the shaded horizontal bars represent the ages of these longest-duration high variability stages (From Potts and Faith 2015)



behavioural plasticity would be most competitive (Grove 2011, Potts and Faith 2015); Grove argues this period may even extend to as late as 1.2Ma (Grove 2011, Grove 2012, Grove et al. 2012). This period is also one in which there is a pattern of extinctions amongst the African large carnivore guild (Hoare Pers. Comm. - unpublished data), including cursorial predators and an ursid *(Agriotherium africanum)*, due perhaps to resource scarcity and an inability to sufficiently adapt to changing conditions. This is also roughly the same period from which the earliest identifiable lithics have been excavated, Lomekwian material (Harmand et al. 2015), which is here taken as a clear archaeological demonstration of behavioural plasticity. These technological innovations coupled with observable morphological adaptations clearly highlight hominin behavioural plasticity at this time. However, this study wishes to avoid mobilising simplistic relationships by relating every perturbation in the faunal or palaeoclimatic record to a specific technology or adaptation; examples are here used to highlight the heightened behavioural plasticity rather than to make direct correlations.

Environmental heterogeneity promotes behavioural flexibility and therefore environmental heterogeneity benefits versatilists over generalists or specialists (Grove 2011). Plio-Pleistocene changes in climatic trends and patterns of seasonality observable in the archaeological record created sufficient hominin niche plasticity to provide the platform for behavioural adaptations to initiate, and if successful, spread and stabilise. The preferential exploitation of the Wildfire Package, as FAF later proposes, should be viewed as one of a number of new behavioural traits (e.g. stone knapping, fission-fusion, power scavenging) that boosted the biological fitness, through the acquisition of adaptive pay-offs, of those who successfully experimented with innovative adaptive landscape-use optimisation strategies.

Not all researchers adhere to the Variability Selection hypothesis. Shultz et al. (2012; 2130) point out that palaeoclimatic proxies provide little evidence for the Variability Selection hypothesis explaining changes in hominin brain size as "*periods of rapid change in hominin brain size which are not temporally associated with changes in environmental unpredictability*". Although this point of view is countered by Maslin et al. (2014: 11) who suggest that "*hominin speciation events and changes in brain size seem to be statistically* *linked to the occurrence of ephemeral (East African Rift System) deep-water lakes".* Shultz et al. (2012) also stress that specifically the Variability Selection hypothesis allied with available palaeoclimatic data does not explain the visible changes in brain size at ~ 1.8 Ma. This identified inability of the Variability Selection hypothesis (but see Maslin et al. 2014) to link hominin brain size observed through the archaeological record with available palaeoclimatic proxies does not however reduce the usefulness of the Variability Selection hypothesis to providing some background to the initial uptake of hominin fire relationships. In this study the Variability Selection hypothesis provides some context and drive for why hominins would want to innovate with novel exploitation of landscape affordances. FAF (see Chapter 4) can help explain mismatches between the palaeoclimatic record and encephalisation trends by showing how the Variability Selection hypothesis can set in motion processes, relationships and trends that eventually result (after a long time-lag) in encephalisation and out-of-Africa migration.

Behavioural flexibility can be directly applied to how hominin archaeologically detectable anatomical and behavioural changes are perceived by researchers; this results in the development of key features of the *Homo* niche (proposed to include fire - as per Burton 2009) being plausibly directly relatable to climatic and thus behavioural variability (Potts 1998). Of particular relevance here may be the part played by 'adaptability'; the role of which is not well understood at all in the evolution of the hominin lineage (Potts and Faith 2015). Adaptability refers to the ecological versatility or flexibility of a population in response to their surroundings, and can improve the ability of an organism to cope with environmental changes, thrive in novel environments and colonise new habitats (Potts and Faith 2015).

As the term denotes heightened adaptability begets new adaptations; these enhance the versatility of an organism in how it interacts with its surroundings, enabling it to generate a broad suite of adaptive options that can prove vital to coping with the impacts of unpredictable environmental conditions (Potts and Faith 2015). The importance of the variability selection concept to the emergence of *Homo* and its suite of behavioural and morphological traits and autopomorphies, although not proven, should not be underestimated. It is argued here that it provides a solid theoretical background to the uptake of fire-use by Late Pliocene or Early Pleistocene hominins as the two important expectations for identifying this process (as proposed by Potts and Faith 2015) can be met. Namely: i) key adaptations would have evolved and spread during intervals of high climate and landscape variability (highlighted in Fig. 2.3); and, ii) adaptations driven by exploitation of Wildfire Package affordances would enable hominins to adjust to (and benefit from) novel environments.

The diet of early members of *Homo*

Diet, energy and nutrient provisioning are central to understanding hominin paleoecology (Ungar 2004). Within the hominin lineage diet has long been regarded as one of the major evolutionary driving forces for morphological, social and cultural change (Brown et al. 2013). In hominins dietary changes have been associated both with encephalisation and changing social complexity (e.g. Foley and Lee 1992, Wrangham 2009). *Homo* requires a rich diet (e.g. Leonard and Robertson 1992, Aiello and Wells 2002, Wrangham 2009). The distribution of nutrients on the landscape can be described as the ‘nutriscape’; an organism’s diet is the result of nutriscape exploitation (Brown et al. 2013). Fire is a transformational force: ash or the charred remains of plant and animal matter can be viewed as merely a readily accessible form of ‘minerals on the landscape’.

Certain nutrients are essential for basic survival including reproduction (Brown et al. 2013). Modern humans need to consume more than fifty nutrients (Brown et al. 2013). This breadth of nutritional intake should be extrapolated to all *Homo*, even the earliest or transitionary members. These are primarily micronutrients, vitamins and specific minerals, but also include specific amino acids and the essential polyunsaturated fatty acids (mainly obtained from plant sources), linoleic acid (LA) and α-linoleic acid (Brown et al. 2013). Nutrients are traditionally divided into five major groups (proteins, carbohydrates, lipids, vitamins, minerals) (Brown et al. 2013) plus water. Whilst animal (vertebrate and invertebrate) and plant tissues compose the principal sources for all five groups the right kind of habitat can also directly supply some essential minerals (including Fe, S, Ca, Na and Se) (Brown et al. 2013); this includes wildfire burnt environments.

To be successful an organism must obtain sufficient energy and nutrients to fulfil all requirements (Oftedal 1991, Foley 1993, Burton 2009); the nature of foraging strategies chosen, resource quality and time spent foraging can be crucial factors to attaining this (Oftedal 1991, Ungar et al. 2006, Organ et al. 2011). Changes in foraging strategies can lead to subsequent changes in energy budgets (Ungar et al. 2006). The less time spent finding food means more time for other activities (e.g. grooming and other social activities). Perhaps due to the ‘competitive aspect of natural selection’ the assumption is made that, to generate maximum adaptive selective pay-offs, behaviours need to be ‘optimised’. One theory based on this idea is ‘Optimal foraging theory’, a behavioural ecological theory often used in ecosystem modelling exercises that makes predictions about the nature of foraging behaviour (Bird and O’Connell 2006).

Optimal foraging theory predicts that organisms will forage in such a way as to maximise their net energy intake per unit time (MacArthur and Pianka 1966: 603), and therefore that an organism should forage where it is most profitable and where it incurs the least costs in obtaining food resources (Laundre et al. 2009). The energy efficiency of an organism and the required dietary quality, both potentially important evolutionary pressures, are two of a myriad of parameters that will determine what the optimal foraging strategy for any organism or community is. Primates show a high degree of awareness towards their environment, particularly when it comes to obtaining foraging resources (Foley 1991, Cowlishaw 1997).

A number of different theories have been proposed for the diet and feeding strategy of Plio-Pleistocene hominins which can according to White et al. (2015: 4884) be broadly grouped as a 'search-intensive terrestrial feeding niche'. However distinct differences exist between the diets of different ancient hominins; with increasing dietary breadth (e.g. Sponheimer et al. 2006 *Passim*) and increasing dietary quality (e.g. Leonard et al. 2003) trends evident over time. Changes to dietary breadth and dietary quality (in effect eating a greater proportion of high grade foods [Leonard and Robertson 1992, Allen and Kay 2012]) will be accompanied by many changes (e.g. to foraging strategies, behaviour, tool use and morphology); changes to dietary breadth and dietary quality therefore denote significant niche adaptation. In this study FAF addresses these trends by Wildfire Package exploitation viewed as being stimulated by broadening diets and increasing adaptation to mosaic terrestrial environments with increasing C_4 inputs (Sponheimer et al. 2013, Levin 2015); obtainable by directly eating C_4 grasses or predating on C_4 consumers (e.g. large herbivores or termites). In addition foraging strategies linked to exploitation of wildfire Package affordances can help explain dietary quality increases (discussed in Chapter 4).

Dietary quality may be a good way of quantifying and comparing diets however it only looks at energy inputs not trace elements that can also be adaptively crucial (Power 2016) and may impact on the choice of foraging strategy (Oftedal 1991). In reality choice of foraging strategies and food choice can be driven by net energy intake as well as: i) requirements for specific nutrients; ii) constraints imposed by the digestive system; iii) inter and intra-specific competition; and iv) predation pressure (Oftedal 1991). In *Homo* a shift to a higher quality diet is a suggested precondition of encephalisation (Bunn 2001) as brains are extremely expensive to both grow and maintain (Shultz et al. 2012). The increase observed in the brains of early members of *Homo* may have imposed a ~ 20% increase in metabolic costs (Leonard and Robertson 1992).

In an evolutionary context, a ‘significant’ amount of high-grade resources has been suggested to correspond to a shift from 10% to 20% of food intake (Psouni et al. 2012). Shifting to a higher quality diet requires increased ‘choosiness’ and therefore larger range sizes. Shifting to a higher quality diet is a fundamental feature of many theories that attempt to observe and elucidate the differences in lifeways between *Homo* antecedents and *Homo* (e.g. models that posit an increase in big game hunting by Plio-Pleistocene hominins). Aspects of the FAF model (elucidated in Chapter 4) can be used to explain the transition to a higher quality diet in a number of ways, by showing: i) how the relative quality of available resources can be improved; ii) how harvesting rates can be safely increased by reducing investments in vigilance; and, iii) how giving up densities (GUDs) can be reduced.

Research by Sponheimer et al. (2013) confirmed that hominin diets changed dramatically from that eaten by modern chimpanzees (not necessarily the ancestral state) between 4Ma and 3.5Ma. Sponheimer et al. (2013) used isotopic analysis to study and categorise dietary shifts, observing a distinct increase in C_4 resources consumed. It should be noted that isotopic analysis while being a powerful protein measuring tool for reconstructing hominin food sources (note: analysis does not identify the intake of important low-protein foods - e.g. underground storage organs) and distinct dietary shifts is not useful for reconstructing long-term energy budgets as the only information provided regards the sources of dietary protein consumed over a number of years (Richards and Trinkhaus 2009). A distinct shift in diet would almost certainly be associated with changes in resource and habitat use themselves associated with increased behavioural plasticity. Behavioural plasticity is particularly important for animals that want to successfully utilise mosaic (multiple) habitats, as adaption to changing and unpredictable threats occurs through the use of a plastic set of cognitive and behavioural systems (Mobbs et al. 2015) and may include dietary shifts. In hominins dietary shifts can be an important precursor, or concomitant with, changes in foraging toolkits. While hominin dietary changes between 4Ma and 3Ma are easily theoretically linked to changes to hominin toolkits (e.g. lithic technologies) they can also be explained by the exploitation of Wildfire Package affordances (in this study fire-use is regarded as a form of tool-use).

To stimulate dietary changes some sort of perturbation or disruption to the niche is required; important dietary changes could have taken place under conditions of varying resource availability (Potts 1998, Shultz et al. 2012, Potts and Faith 2015) and may have stimulated the emergence of social feeding which requires specific conditions to be met e.g. a high resource density to attract and satisfy a group of foragers (Foley 2001). Social feeding is suggested to have enabled the increase in group size modelled to have occurred during the transition to *Homo* (Mithen 1996) that subsequently significantly affected and guided the evolutionary trajectories of *Homo*. If exploitation of Wildfire Package affordances enabled the dense resources required then this would not only support ‘early fire’ theories and models but by ‘flipping’ the idea round it could then be argued that Late Pliocene hominin exploitation of Wildfire Package affordances can help further resolve the prevailing conditions and environments chosen for the evolution of important social adaptations such as increased group sizes (with associated enlarged ranges), and social feeding adaptations.

Increases to the dietary quality of early members of *Homo* are morphologically and behaviourally manifest in a number of ways (Organ et al. 2011). Organ et al. (2011) argued that dietary quality improvements can lead to a decrease in the overall time spent feeding and digesting (Organ et al. 2011). This is due to less chewing and ingestion time, which would allow more time for other things, e.g. grooming, tool-making, childcare or other behavioural adaptations that lead to an increase in social and behavioural complexity. Leaf foods (a quintessential low grade resource) require large amounts of digestion time as well as additional costs in terms of time and energy inputs for detoxification (Foley and Lee 1992).

Dietary quality improvements have also been suggested to lead to earlier weaning (Psouni et al. 2012). The size of a mammal's brain is (to some extent) limited by the energy available to the mother during pregnancy and lactation (perhaps less so in humans due to 'secondary altriciality', suggested to be a direct result for the need for large brains [Bunn 2001]). A mother's energy budget during pregnancy and lactation is of vital importance and must be maintained in spite of any short-term resource stress; access to the relevant quality (and quantity) of diet is crucial (Aiello and Key 2002). Having a large brain imposes additional energetic costs on mothers and infants (Foley and Lee 1992, Aiello and Key 2002, Steudel-Numbers 2006). Bunn (2001) proposed that during the evolution of the genus *Homo*, and then steadily over time, mothers/females must have improved their quality of diet, this possibly required a rise in trophic status (a repositioning within the food web). Although early members of *Homo* had relatively small brains, their diet must have been capable of providing sufficient maternal energy levels throughout the annual cycle to permit subsequent encephalisation (Rose 2001, Steudel-Numbers 2006); the remaining question is how was this energy budget met? The FAF hypothesis plausibly addresses this issue (Chapters 4 and 7).

A higher quality diet can not only help brain growth to occur, in an evolutionary sense it can enable the shortening of the duration of lactation and suckling (e.g. early weaning) by providing high quality weaning foods and also by increasing infant growth rates (Psouni et al. 2012). This in turn leads to the possibility of shorter inter-birth and higher rates of reproduction intervals (suggested by Shultz et al. 2012 to be potentially linked to increased predation pressures), which would have knock-on effects (Shultz et al. 2012) in terms of increased biological fitness of species and (potentially large) alterations to population dynamics (Wrangham and Carmody 2010, Psouni et al. 2012). The 'stacking' of weaned, but immature offspring would have caused knock-on consequences for amongst other things: social group structure, foraging behaviour, the evolution of cooperative breeding and crèches (Shultz et al. 2012 *Passim*).Very high energy inputs during suckling are especially important as energy transfers between mothers and offspring are much less efficient than during gestation and due to increased physical activity and thermoregulatory stress (relative to foetus) infants have much greater energy demands (Bunn 2001). According to Psouni et al.'s (2012) analysis the modern human weaning pattern is derived specifically from the early *Homo* pattern and is due to an increase in the consumption of high grade resources ~ 2.6-2.0 Ma which fits well with later stages of FAF; exploitation of Wildfire Package affordances and impacts on care-givers infants, juveniles and nurseries are further discussed in Chapter 4.

Gut size in primates (and particularly higher primates) is highly correlated with diet (Miltor 1999); a small gut is compatible only with high-quality, easily digestible food (Aiello and Wheeler 1995). Wrangham (2009) argues that morphological changes between *Homo* and *Homo* antecedents requires early fire. Small guts are characteristic of animals that consume easily digestible diets and have been identified as a proxy for a high quality diet (i.e. a diet high in fat, protein, and simple carbohydrates and low in structural carbohydrates) (Allen and Kay 2012). In primates small animals tend to have high quality diets (e.g. *Tarsius spectrum*), while large animals (e.g. *Gorilla gorilla*) have low quality diets. However *Homo* is an anomaly, because *Homo* can be regarded as a genus of large animals (perhaps with the exception of *Homo floresiensis*) with a high quality diet. The combination of large brains and small guts appears to be a specific *Homo* autopomorphy.

Meat

Animal foods are an attractive resource for omnivores because of their greater caloric density and digestibility relative to plant foods (Leonard and Robertson 1992, Stiner 2002, Ungar et al. 2006, Wrangham 2009). Sourcing meat (a high quality resource due to high protein levels and low digestive costs [Bunn 2001]) is a rewarding but risky strategy that, nevertheless, is viewed as increasing in significance during the evolution of *Homo* (Stanford and Bunn 1999, Organ et al. 2011). Hominins with sufficient technology to attain increased levels of carnivory could have significantly increased their net energy intake (Ungar et al. 2006). An increased level of carnivory requires competing with other members of the carnivore/ scavenger guilds which (it is proposed here) requires new relationships and self-framing and associated neural architecture and altered ‘Landscapes of Fear’ (discussed in depth in Chapter 4). An important suggested impact of increased carnivory is that as meat resources are more widely dispersed than foliage, increasingly carnivorous hominins should also be more widely dispersed and more tolerant of habitat differences (Bunn 2001); in essence an increase in carnivory will select for eurytopic or widely ranging groups (Bunn 2001)[5].

Entomophagy can also be viewed as a kind of carnivory. Insectivory is important to many primates including panins (Whiten et al. 1999) and pongids (Fox et al. 1999) and may have been very important to ancient hominins (Backwell and d’Errico 2000, Rose 2001). It has suggested to have made a seasonal notable contribution to diet (nutritionally if not

[5] Post-Viva it was suggested that intensive grinding (through lithic or non-lithic tool use) could provide an alternative route for ancient hominins to obtain nutrients and calories.

calorifically) (Rose 2001), and importantly it would have been potentially significantly less risky than hunting or scavenging because competitors would be either nocturnal specialist insectivores (e.g. aardvark) or small generalist carnivores (e.g. meerkat) (Rose 2001) and not the larger and more fierce competitors for more substantial prey (e.g. felids and hyaenids).

Fallback foods

The nutriscape is constantly changing depending on the complex interaction of a broad range of biotic and abiotic factors (Campbell and Reece 2005). For hominins during times of scarcity ‘fallback foods’ become more important (Laden and Wrangham 2005), as do habitats from which a relatively high quality diet can be attained (‘fallback foods’ are normally used to denote resources of relatively poor nutritional quality that become particularly important dietary components during periods when preferred foods are scarce [Marshall and Wrangham 2007, Marshall et al. 2009]).

The ability of hominins to utilise high quality ‘fallback foods’ during times of resource stress would confer a selective advantage providing the overall costs of accessing the high quality resource is not overly great (e.g. a high risk of mortality while obtaining access to the resource); due to the seasonal nature of wildfire (wildfires are often associated with dry seasons and the often violent thunderstorms that presage the start of rainy periods) some Wildfire Package affordances can be modelled as being high quality fallback foods (e.g. honey gained through the deployment of smoke). In periods of seasonal resource scarcity Wildfire Package affordance exploitation could impact on biological fitness in a number of ways. While fat is the major energy reserve in hominins and can buffer food scarcity (Brown et al. 2013) other extremely high energy foods are an obvious attractant for hominins. Underground storage organs (e.g. Laden and Wrangham 2005, Yeakel et al. 2014) and termites (e.g. Backwell and d'Errico 2000) have been oft implicated for their importance in hominin evolution (Sponheimer and Lee-Thorpe 1999), both of which can be easily identified and collected in a wildfire burnt environment (personally observed during South African fieldwork in 2012); honey is another potentially important hominin fallback food whose acquisition can be linked to exploitation of the Wildfire Package (Wrangham 2011).

Honey in hominin diets

Honey is focussed on in this thesis as it is a particularly obvious attractant for foraging hominins and can be used as a hominin fallback food (Crittenden 2011). A suggestion of ancient hominin honey-use links well with the FAF hypothesis (outlined in Chapter 4) as honey is unlikely to have made a major contribution to diet until Wildfire Package affordances were exploited (as per Wrangham 2011). Without the control of fire it would seem impossible for a genus vulnerable to bee stings, such as *Homo*, to obtain large amounts of honey without utilising smoke (Kraft and Ventakaraman 2015). Wrangham (2011) suggests that by using a combination of lithic (and maybe also wood or bone) technology and smoke (as well as some sort of basic container – e.g. a tortoise shell or leaves) early members of *Homo* may have been the first hominins equipped with the necessary cognition and tool-kit to extract significantly more honey than modern day panins; at the same time building a mutualistic relationship with honeyguides. Wrangham (2011) suggests that this relationship appeared with *Homo*; however evidence does not constrain heightened hominin honey extraction to *Homo.* The possibility exists that this was a significant novel foraging strategy linked to Wildfire Package affordances with potentially very significant adaptive selective pay-offs and forces that may have helped to energetically fuel the '*Homo* antecedent to *Homo'* transition. The increased extraction of honey is one clear way that exploitation of

Wildfire Package affordances can provide a significant diet and energy related adaptive selective pay-off to ancient hominins.

The procurement of honey is high risk due to the defensive strategies of bees (primary African honey producers) as well as the very often difficult to access location of hives. Compensating for these high risks, honey is exceptionally nutrient (Crittenden 2011, Wrangham 2011) and energy rich (86 g 100 g−1 - Brown et al. 2013), can often be found in large amounts and perhaps very importantly it tastes really good. A significant increase in the consumption of honey has the capacity to impact on the overall dietary quality of an organism (Kraft and Ventakaraman 2015) particularly during times of resource stress. Despite repeated suggestions that it may have been an important food source for early members of *Homo*, it has received little attention in hominin diet reconstructions (Crittenden 2011 *Passim*). The use of smoke from a smouldering branch effectively enables increased access to honey contained in a beehive, potentially netting kilograms of nutrient and calorie rich honey in addition to fat and protein rich larvae (Wrangham 2011, Kraft and Venkataraman 2015). The ability to use smoke enables honey hunters to increase yields and minimise injuries thereby conveying selective advantages over non-smoke using honey hunters; even those using plant secondary compounds (see Kraft and Venkataraman 2015 *Passim* for information on how smoke works to effectively reducing apiform defensive responses and stinging behaviours (Kraft and Venkataraman 2015). The ability to use smoke by ancient hominin honey hunters would have enabled injuries to be minimised and increased yields thereby conveying selective advantages over non-smoke users.

Due to its nutrient density it is a major component of the diet of chimpanzees and many groups of African hunter-gatherers (Crittenden 2011, Wrangham 2011). Honey even vies with meat in its desirability and influence on energetics, nutrition and also social factors (renowned honey gatherers accrue a lot of social capital which results in distinct fitness benefits) (Wrangham 2011); for example Marlowe and Berbesque (2009) found that of the five major food categories (tubers, berries, meat, baobab, and honey) Hadza ranked honey highest. Great apes have a strong appetite for honey, chimpanzees especially; all *panin* species have been observed eating honey (Crittenden 2011, Wrangham 2011). Parsimoniously a deep 'interest' in honey is categorisable as the 'ancestral hominin condition' (although it is again noted that extensive parallelism occurs among higher primates - White et al. 2015). A deep 'interest' in honey as the ancestral condition is backed up by the knowledge that honey is very common in many African habitats (Kraft and Ventakaraman 2015), particularly savannah (the habitat with the highest fire frequency) with up to 18 hives per km^2 (Wrangham 2011).

Despite the fact that honey is archaeologically invisible (due to an absence of paleo-pathological tests) evidence for ancient hominin extraction of large amounts of honey exists in avian form (Wrangham 2011). The 'honey guide' (*indicator indicator*) has over time developed a form of symbiosis with hominins whereby the bird leads a forager to the site of the hive and benefits either directly and/or indirectly from hominin hive penetration (in many instances modern hunter-gatherers leave 'booty' behind for the bird as a gift) (Crittenden 2011). This is an evolved as opposed to learned behaviour due to the Honeyguide's reproductive strategy of 'brood parasitism' (Wrangham 2011). No methodology exists to enable a theoretically robust assessment of the amount of time required to form this mutualistic symbiotic relationship, but a reasonable conclusion to draw is that at some point significant adaptive selective pay-offs accrued to both parties (i.e. large amounts of honey were extracted) leading to the stabilisation of the Honeyguide/hominin relationship.

The importance of understanding ancient hominin foraging behaviour

While the Wildfire Package offers many exploitable affordances, not all of which are in the foraging realm, an understanding of foraging behaviour is crucial to gain good quality insights to hominin evolution. Hominin evolution is characterised by two major systematic changes - bipedalism and encephalisation; both of which are directly attributable to foraging behaviour and strategies (Foley and Lee 1992). Encephalisation probably required both increased foraging efficiency *and* incorporation of higher quality foods into diets in substantial quantities to be able to sustainably fuel brain growth (Foley and Lee 1992, Ungar et al. 2006). A clearer understanding of palaeodiets appears fundamental to creating a good model of the paleoecology of Plio-Pleistocene hominins from which foraging strategies can then be determined. However improving resolution of ancient hominin paleodiets is limited by sparse information regarding the foraging strategies deployed (Ungar 2004). This is a circular argument; if better dietary information were available then clearer insights would be obtainable into foraging strategies used, and *vice versa*.

The archaeological record is obviously extremely useful and should always be the first place researchers should look for information from which to construct models. The quality and nature of the archaeological record (highly spatially and temporally limited and patchy) and available scientific methodologies have until very recently provided insufficient precision to Plio-Pleistocene hominin palaeodiets. This study started with the viewpoint that all Plio-Pleistocene dietary and foraging models should be viewed as ‘purely speculative’ however recent improvements to isotopic studies have resulted in good quality insights now being available (e.g. Sponheimer et al. 2013 and Levin et al. 2015); specifically regarding the Late Pliocene uptake of a C_4 diet by multiple hominin taxa (Sponheimer et al. 2013). The unequivocal incorporation of C_4 resources by hominins as early as 3.76Ma demonstrates increased dietary breadth and a widening range of environments that hominins were able to exploit (Levin et al. 2015); this is good evidence of evolving hominin niches incorporating increasing levels of savannah/bushland. Frustratingly precision is still lacking within Plio-Pleistocene palaeoenvironmental and palaeoecological reconstructions. Therefore the specific nature of Plio-Pleistocene hominin foraging strategies, and how and when these strategies adapted, is not known with any confidence. Researchers can only make inferences from data available and create the 'most elegant, best-fit' models. This realisation underpins this study.

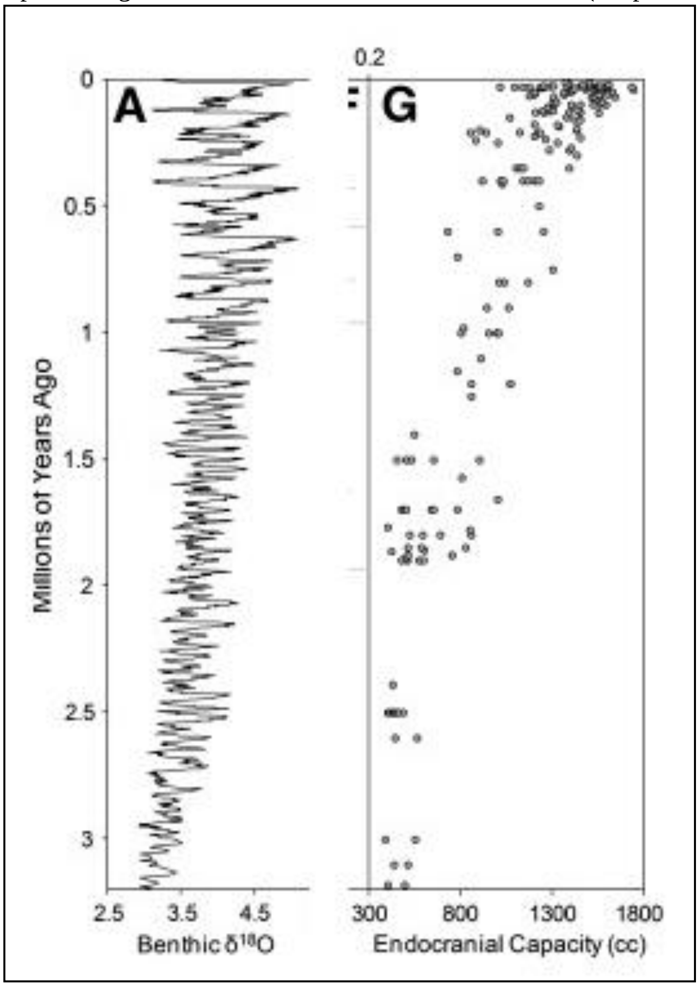
Neurological implications of the emergence of *Homo*

New niches require new behaviours including new landscape uses (e.g. diets, foraging strategies), which in turn creates new relationships with landscapes and other aspects of foodwebs, predators and prey. It is proposed here that neural architecture generated during the emergence of the genus *Homo*, would then be part of the broad niche of that entire genus. As well as unique morphological and behavioural traits it is proposed here that *Homo* must have had a suite of unique psychological traits. Amongst these would be new relationships and ways of framing landscape externalities such as wildfire, and new ways of creating mental landscapes. It is proposed here that the deployment of a suite of innovative relationships with landscapes would require LOF adaptations that would impact on pre-existing neural architecture necessitating physical changes in the brain. This would be especially true if this broad suite of adaptations included a rise in trophic level or a repositioning of the species within local foodwebs.

A change in trophic positioning requires a new way of self-framing, and thus altered ways of interacting with both prey and predator species which would entail changes in risk management and environmental interactions. For this reason a reorganisation of the place in a foodweb is hypothesised here to require more reorganisation of neural architecture than a simple change in the physical quality of diet. If sufficient behavioural and morphological adaptations occurred in a short period, each ‘feeding-back’, ‘ratcheting’ and impacting on each other, significantly changing both behaviour and morphology to such an extent that a new genus of hominins emerged then it seems likely that this might have entailed some degree of cognitive reorganisation. During this reorganisation of neural architecture strongly selected for traits would be imbed. Subsequent encephalisation would then build new layers upon this pre-existing (limbic) neural architecture. This would result in modern humans possessing behavioural relics of evolutionarily important ancestral behaviour, thinking, mindsets and ways of framing the world that moulded the emergence of the genus to which we belong. The modern human minds’ mosaic of inherited traits includes those from evolutionary specialisations within particular domains (Sherwood et al. 2008); FAF states that one of these domains was the Wildfire Package (elaborated in Chapter 4).

With respect to *Homo,* archaeologists and paleoanthropologists determine cognitive ‘capacity’ by estimating the volume of endocranial casts (see Fig. 2.4 for broad trends in hominin endocranial capacity over the past 3.5Ma), which while broadly useful does not allow researchers to reach robust observations regarding the actual internal mechanics of the brain; while endocasts can also provide an impression of the external morphology of the brain, critical information regarding internal neuroanatomical organisation is not determinable (Sherwood et al. 2008). This is a real problem as “*while increased brain size undoubtedly has been central to the evolution of modern human cognition, other modifications to brain development, structure, and function are also certain to be significant*” (Sherwood et al. 2008; 427).

Fig 2.4: A composite picture of palaeoclimatic change and human brain evolution over the last 3.2 million years. Plot ‘A’ displays the raw data of the LR04 stack, an aligned stack of 57 globally distributed palaeotemperature records (after Lisiecki and Raymo, 2005). Plot ‘G’ demonstrates the pattern of human brain evolution over the period, with each point representing a distinct fossil endocranial measurement (adapted from Grove 2012).



As well as encephalisation, many other neurobiological aspects have been differentially altered over the last 3-4Ma (Sherwood et al. 2008).Without the discovery of exceptionally preserved ancient hominin brain material it will not be possible to identify the specific architecture present in their brains and then compare it with later or modern material. Without living specimens of ancient hominins to study it appears that the best available source of information regarding the brains of the earliest member of the genus *Homo* would be extant members of the genus *Homo;* this is the approach taken in this study.

However it is a strategy not without issues. One way proposed here that behavioural relics could manifest is in a more positive attitude and framing of fire than would be expected (tested in Chapters 5 and 6). If it were to be observed would it be possible to quantify it as a part of the entire *Homo* niche? Hominin fire relationships are not static now, nor would they have been in the past. As *Homo* evolved behaviours technologies and habitats changed, thus the nature of fire-use also would have evolved leading to subsequent adaptations to neural circuitry that may also have been strongly selected for (and which may be very recent); these could obfuscate investigation of more antiquated relationships. This realisation is borne in mind during later data synthesis (Chapters 7 and 8).

Ancient hominin foraging – 'known unknowns'

When viewed from a Rumsfeldian[6] perspective, a plethora of ancient hominin 'known unknowns' exist. Modern ecosystem compositions are very different to their Plio-Pleistocene counterparts, comparisons with which are obstructed by a number of issues. Important 'known unknowns' relevant to this study relate to ancient hominin carnivory, entomophagy and the nature and behaviour of Plio-Pleistocene African large carnivore guilds. The current distribution of the scavenger and carnivore guild is almost entirely anthropogenically determined (e.g. through the gazetting of National parks and top-down human pressure on prey species). Key niches in the Plio-Pleistocene ecosystem have also become extinct (e.g. the niche occupied by sabre-tooth cats like *Homotherium*). When these fundamental issues are added to the weaknesses mentioned earlier (e.g. regarding the successful identification or recreation in detail of ancient hominin foraging strategies and diets), then any attempt that proposes to illuminate the specific nature of ancient hominin lifeways is further weakened.

[6] Donald Rumsfeld was the 21st Secretary of Defense from 2001 to 2006 under President George W. Bush; his autobiography was titled '*Known and Unknown: A Memoir'*. There are 'known knowns" is a phrase from a response Donald Rumsfeld gave to a question at a U.S. Department of Defense news briefing in February 2002.

Ancient hominin entomophagy is a 'known unknown'. Insects and other invertebrate resources are important food sources for a number of primate and ape species, but are bizarrely an oft-ignored potentially very significant part of Plio-Pleistocene hominin diets (Backwell and d'Errico 2000, Rose 2001). Greater understanding of how and where energy cards were being balanced would greatly enhance current perspectives of the nature of adaptive selective pay-offs that steered hominin evolutionary trajectories. Another specific 'known unknown' concerns the levels of carnivory and meat consumption of ancient hominins. In the Pleistocene little doubt remains that hominin meat-eating became increasingly important (Wrangham 2009), but due to a dearth of good evidence a lack of consensus exists as to how often meat was obtained, consumed, how exactly it was procured, and what proportion of the diet was meat (Foley 2001); all of which could feasibly have impacted on hominin morphological and behavioural development (Foley and Lee 1992, Leonard and Robertson 1992, Bunn 2001). Technological innovations and novel behavioural strategies would have provided hominins with the opportunity to experiment with new dietary adaptations that probably included greater amounts of meat than that eaten by their antecedents (as per Foley 1993); what these were or which habitats were chosen to deploy them in is open to conjecture. Other very important 'known unknowns' relate to both the nature and scope of the root of hominin fire relationships.

A deep fire root

Like all evolutionary behavioural changes (e.g. the uptake and development of lithic technology) the onset of anthropogenic fire-use would have very likely been a very gradual and highly nuanced process (as per Burton 2009). The development of Mode 1 fire technologies and fire/hominin interactions was most likely an incredibly slow long drawn out affair, played out over many millennia and hundreds or thousands of generations. This can be termed hominin fires' *deep root*; and it may be very deep indeed (Burton 2009). The nature and scope of this deep root is central to this study. Pruetz and LaDuke (2010: 649) suggest that the conceptualisation of fire should be seen as the *deepest tip of the fire root*[7]. Once an understanding existed for the behaviour of fire under different conditions then a range of different responses and strategies could be developed. Here the case is set-out that a deep root of Mode 1 fire-use pre-dates all known 'out-of-Africa' migrations, and may have played an important part in the evolutionary process that enabled hominins to leave Africa. It is not stated here that all individuals in all groups would have been aware of the properties and affordances of fire, as there is no way of determining whether all individuals would have had first-hand experience of fire (and some hominin groups would have inhabited more fire-prone environments and climatic conditions than others). To support the deep root it would have to be assumed that sufficient contact with the Wildfire Package was had by ancient hominins to maintain selection and retention of traits. In this study a date of 2Ma is used for the earliest out-of-Africa migration as although the earliest known 'out of Africa migration' occurred at about 1.8Ma (Lordkipanidze et al. 2013), it is entirely feasible that new finds could push this date back further.

The Gesher Benot Ya`aqov evidence, which has been dated to 'significantly earlier' than ~0.79Ma (Alperson-Afil et al. 2007, Alperson-Afil 2008, Alperson-Afil and Goren-Inbar 2010) is now viewed by the wider research community as the earliest credible evidence for repetitive anthropogenic fire-use. Gesher Benot Ya`aqov evidence, derived from a range of methodologies, suggest that fire was continually used by a resident population of Acheulian hominins (Alperson-Afil 2008); recovered evidence includes burned wood and grains, charcoal fragments and spatially clustered burned flint micro-artifacts (Alperson-Afil el al.

[7] My terminology

2007). This population was already outside of Africa and lived ~1Ma after the earliest evidence of *Homo* outside of Africa (Lordkipanidze et al. 2013) and ~2Ma after the oldest evidence of *Homo* (Villmoare et al. 2015); Gesher Benot Ya`aqov evidence is also roughly contemporary with the earliest evidence for British *Homo* (Ashton et al. 2014).

It could be argued that any assertion of hominin fire-use that pre-dates Gesher Benot Ya`aqov is ‘Early fire’ (i.e. fire-use earlier than widely recognised), but in this study the definition of Early fire as being anything ‘*earlier than fire-use by Middle Pleistocene hominins*’ does not really fit with the ideas that hominin fire interactions: i) in some simple ways predate *Homo*; ii) are a key construct of the *Homo* niche; iii) helped drive hominin encephalisation trends; and/or iv) helped drive the initial appearance of *Homo*. Therefore in this study ‘Early fire’ is defined as ‘*any repeated deliberate hominin use of fire and wildfire created resources that predate the earliest known out-of-Africa migrations*’.

Coherently modelling the earliest hominin fire-use

Like all coherent models, early fire models must include key ‘real world’ processes (in a simplified form), so that trends relationships and patterns can be identified (Gentleman 2002). Researchers will never know with 100% confidence what the nature was of the very earliest hominin fire interactions but a number of very simple ways to benefit from the Wildfire Package can be envisaged (Table 2.2). All of these uses (and Table 2.2 should not be viewed as an exhaustive list) can be modelled as conveying some immediate adaptive selective advantage or fitness benefit to the animal or group deploying this strategy. For example travel times can reduce along with investments in vigilance when omnivorous primates (e.g. *Chlorocebus aethiops*) inhabit newly burnt environments (Enstam Jaffe and Isbell 2009).

Early fire proponents face many of the same issues and obstacles as proponents of many theories concerning the strategies and lifeways of ancient hominins. Namely that many ideas abounding in the literature about early hominin behaviour are framed more by the personal paradigms of individual researchers (or prevalent paradigms) than on unambiguous data-supported arguments (Domingues-Rodrigo 2002). While this is undoubtedly the case with early fire it is the lack of unambiguous data-supported arguments that help to reinforce existing paradigms which often fall within the realm of 'what you see is what there was'; but there is so much missing from the archaeological, palaeoenvironmental and fossil records that researchers should not be lured into thinking important only what is preserved (Gamble et al. 2014). It is very important to clearly acknowledge that ideas about anthropogenic fire that predate firm archaeological evidence will always by their very nature be classed as NOT unambiguous data-supported arguments; this includes hypotheses forwarded in this study.

A 'what you see is what there was' mind-set for the study of the onset of deliberate opportunistic hominin Wildfire Package affordance exploitation essentially renders as 'un-researchable' the earliest deliberate hominin fire interactions that are proposed in the FAF model later in this study. This mind-set ignores the fact that the very earliest and most simple 'hearths' would possibly be a 'natural hearth' (e.g. the hole created when tree roots burn) or 'un-structured hearths'. These most simple hearths (without stone augmentation) are indistinguishable from tree root fires not used by hominins, and thus were they to be identified and published by researchers would not stand up to scrutiny (Bellomo 1994); even Mesolithic non-structured hearths leave barely identifiable traces (Sergant et al. 2006). To further our understanding of this key period in human development, discussions about Mode 1 fire-use must move away from a 'what you see is what there was' mind-set. It is hoped that data and arguments presented in this study can generate a case that can help to break down existing ‘what you see is what there was’ perspectives and help strengthen the paradigm that sees Plio-Pleistocene hominin-fire relationships as a key part of the toolkit which allowed *Homo* to develop their distinctive behavioural and technological adaptations and build their unique successful niches.

One reason early fire matters is because if a date of ~0.79Ma, (or even 1MA to allow for the fact that the archaeological record rarely, if ever, shows the initial appearance of an adaptation or behaviour) is accepted for the initial onset of hominin fire-use then Wildfire Package affordance exploitation cannot then be used to explain some of the morphological, behavioural, social or cognitive changes and adaptations that are visible in the archaeological record prior to this date (e.g. the *Homo* body-plan, dietary changes or major encephalisation). Furthermore it must then become accepted that hominins were able to migrate (repeatedly) out of Africa and into northern latitudes (amongst other locations) without the benefits of a close association with fire. However if early fire (as defined in this study) is accepted along with a much deeper root, it becomes possible to mobilise aspects of hominin/fire relationships to aid explanation of morphological, behavioural or cognitive changes and adaptations that occurred during the Early and Middle Pleistocene and even the Late Pliocene.

Evidence and theoretical support for the deep root of fire can be collected from a number of diverse sources including ethology and the archaeological record. A deep root of fire would support the idea that interactions and relationships with fire may be a core construct of the *Homo* niche. Millions of years of interactions with the Wildfire Package by increasingly intelligent inquisitive hominins would afford numerous opportunities for a relationship to develop and expand. A ‘very deep root’ for anthropogenic fire-use links with the fact that the African savanna mosaics and increasingly dry forests inhabited by *Australopithecus* and

Homo (and also the LCA?) are characterisable by an increasing (long term trend) amount of highly flammable C_4 grasslands (Bobe 2006).

A	Obtaining a smouldering branch from a wildfire to access honey or reduce parasite loads (which could then lead to the deliberately placing of a branch into a 'rootball' fire so as to make it smoulder to access honey or reduce parasite loads)
B	Ambushing or hunting animals, birds or insects fleeing a wildfire burnt environment
C	Foraging for cryptic animals (e.g. tortoise) which are easier to find after a wildfire
D	Foraging for small mammals, insects or birds which have been killed or injured by wildfire
E	Foraging for new growth of grass and other plants after a wildfire
F	Using smouldering remnants of a wildfire for warmth on a cold night
G	Utilising the wider field of view afforded by a wildfire burnt environment for safety and to reduce investments in vigilance
H	Using a wildfire burnt environment as a safe place for a nursery, crèche, or to give birth
I	Using a wildfire burnt environment as a safe place to groom, socialise and/or knap
J	Using a wildfire burnt environment as a way to reduce parasite loads
K	Taking advantage of fire's impacts on the behaviour of non-fire-utilising conspecifics or other animals
L	Foraging for birds' nests or underground storage tubers which are easier to locate after a wildfire
M	A way of satiating primate curiosity, particularly in young or juvenile individuals
O	Using a wildfire burnt environment as a way to reduce investments in movement and travel times
P	Reducing search times for prey thus improving the harvesting rate for some foraging strategies
Q	Hunkering next to a smouldering log to reduce investments in internal heat production
R	Foraging for pyrophilous insects that congregate near embers

Table 2.2: A non-exhaustive selection of plausible Mode 1 hominin fire-use strategies

At the start of this study it was ambitious to consider deliberate hominin fire interactions at 2Ma or before. All of the direct evidence proposed for fire between 2Ma and 1Ma had been intensively analysed and debated in published material and found to not be robust enough. In addition the prevailing paradigm that only *Homo* had the cognitive capacity for complex tool use (fire is a tool) meant that the concept of modeling pre-*Homo* deliberate hominin fire interactions was unlikely to gain traction. Subsequently a number of discoveries have been published which enable a rapidly emerging paradigm shift in palaeoanthropology and the 'pushing back' of this timeline (Lewis and Harmand 2016). Aspects of this emerging paradigm shift include (but are not limited to): i) New earlier lithic industries; ii) New osteoarchaeological finds; and, iii) Older dates for the emergence of the genus *Homo*.

Lithic finds from Lomekwi 3 firmly dated to ~3.3Ma by a combination of $^{40}Ar/^{39}Ar$ dating and magnetostratigraphy (Harmand et al. 2015) depicts significant adaptation in hominin technological behaviour prior to the emergence of *Homo* (Lewis and Harmand 2016). The cognitive implications of lithic technologies being produced at 3.3Ma, and potentially even earlier if the cut marked bones identified at Dikika dated to at least 3.39Ma by McPherron et al. (2010) are accepted as evidence of the use of lithic technology (despite no actual lithic tools being recovered from the site), include: i) an understanding of the fracture mechanics of the available stone raw materials (Lewis and Harmand 2016), and which size and shape of raw material to start with; ii) sensorimotor control over the force and accuracy involved in the successful striking of flakes (Lewis and Harmand 2016); and, iii) a visuo-spatial understanding of the entire knapping process so as to be able to effectively utilise raw material (Lewis and Harmand 2016 *Passim*).

This cognitive development occurs while hominins still had 'almost great ape sized brains' and well before the major encephalisation events associated with Pleistocene *Homo* occur (Shultz et al. 2012). It may have been that a reorganisation of the brain, rather than an enlargement of the brain, was sufficient to allow the incorporation of more complex tools and strategies to hominin lifeways. Moreover the '*flexibility in the Lomekwi 3 hominins'* technological behaviour' (Lewis and Harmand 2016; 4) hints at the behavioural and technological plasticity required to experiment with new technologies and subsistence strategies; no evidence exists to limit behavioural plasticity to lithic technologies. The key message from the Lomekwi data is that if stone tool making might no longer be considered characteristic only of *Homo*, perhaps opportunistic but deliberate exploitation of Wildfire Package affordances should be similarly viewed. Lewis and Harmand (2016; P6) finish their paper with the following thought: "*To search for the roots of our genus and for the behaviours characteristic of what it means to be human, palaeoanthropologists must now focus between 4 and 3 Ma.*" This supports the idea of a deep root for hominin fire-use.

The recent discovery of more than 1500 hominin fossils (Berger et al. 2015, Thackeray 2015), comprising the fossilized remains of at least fifteen hominin individuals, assigned the name *Homo Naledi* (Berger et al. 2015) from the Rising Star cave system in South Africa shook the palaeoanthropological world for many reasons; not least the amazing preservation of material but also the idea that they were deliberately disposed of in a very difficult to reach and dark underground cavern (Berger et al. 2015). What has severely limited the impact of this find is that the material has yet to be securely dated. Two attempts have been published, neither of which engenders much confidence in their conclusions: a date of 2Ma +/- 0.5Ma was obtained by Thackeray (2015) by a least squares linear regression analysis of mean values of measurements for crania (a method susceptible to the retention of archaic features by relatively modern honminins); and a date of 0.912Ma (with a 95% high posterior density interval between 0.000 and 2.388 Ma) was obtained by Dembo et al. (2016) using Bayesian phylogenetic methods.

While the publication of so much undated material has caused consternation in the research community as without accurate dates the material is interesting but essentially useless to support evolutionary hypotheses. It has also caused the rethinking of paradigms concerning both the onset of certain aspects of culture (due to deliberate disposal of mortuarial remains) and the controlled use of fire. How else to explain navigation in dark narrow caverns approximately 30m underground, and some 80m from the current cave entrance, with no conceivable cause of natural light (Dirks et al. 2015). This recent discovery does highlight the way that one new find (in this case a Konzentrat-Lagerstätten) has the ability to both potentially revolutionise the way researchers view the course and nature of hominin evolution and significantly impact on the nature of behavioural hypotheses constructed to explain archaeological finds[8].

Recent Plio-Pleistocene hominin fossil discoveries have fundamentally transformed pre-certain paradigms pertaining to the origins of *Homo*. A synthesis of new material points towards a common conclusion: osteological and behavioural diversity in early members of *Homo* was much broader than previously thought (Lewis and Harmand 2016). Previous theories and models of the emergence and behaviour of early *Homo* were constrained and hampered by the very limited African fossil record in the period 2Ma-3Ma (Villmoare et al. 2015). However a recently recovered securely dated (2.8-2.75Ma) partial hominin mandible, LD 350-1 (from Ledi-Geraru, Ethiopia) has extended the fossil record of *Homo* significantly back in time; *Homo* is no longer constrained to the Pleistocene. In a similar way to the *Homo naledi* material, LD 350-1 displays a combination of derived morphology observable in later

[8] In an article published after the submission of this thesis Dirks et al. (2017) provide relatively secure dating of the *Homo naledi* material using a combination of optically stimulated luminescence dating of sediments with U-Th and palaeomagnetic analyses of flowstones to constrain the depositional age of *Homo naledi* to a period between 236 ka and 335 ka. In the opinion of the author this relatively young age does not detract from the arguments presented in the main text as to the ability of a new find to radically alter existing paradigms.

specimens of *Homo* with primitive traits seen in early australopiths (Villmoare et al. 2015). The discovery of LD 350-1 shows how existing paradigms can be impacted by a single find.

Pre-*Homo* fire relationships

Pruetz and Laduke (2010: 1) suggested that the cognitive underpinnings of fire conceptualisation are a primitive synapomorphic hominin trait as they are present in extant groups of wild chimpanzees which were observed to: "*calmly monitor bush fires at close range and change their behaviour in anticipation of the fire's movement*"; this opens up the idea that small-brained mosaic scrubland/woodland/bushland living Australopiths could also have had similar capabilities. The nature of the ancestral psychological relationship with fire makes a big difference to models of the uptake of hominin fire, particularly those that are psychobiological in nature. In this study assessment is made of two different hypothesised plausible deep ancestral states; one 'risk aware' and one 'risk averse'.

In this study irrespective of the nature of the ancestral condition, a hominin's cognitive processes are viewed as not purely inherited but are formulated with inherited processes overlain with ontogenetic (in the 'anthropological' sense – see Toren 2002) behaviour and inputs gained from personal and compatriots experiences (not nature *or* nurture, but nature *and* nurture) (as per Sherwood et al. 2008). Evolved neural architecture prepares us to react to threats and risk factors, but our own personal experiences and those that we see happen to others are responsible for shaping decision making (as per Mobbs et al 2015). Personal negative (or positive) experiences within an organism's life (particularly if those experiences occur when a neonate or juvenile) may temper or override inherited psychological mechanisms; potentially resulting in a (within group or community) range of complex cognitive relationships with environmental externalities. The impacts of hominin associative learning on the earliest relationships with fire are discussed in greater depth in Chapter 4.

Should Fires deep root be constrained by the LCA?

Accepting the idea that the very earliest simplest hominin fire interactions may date to (or predate) the LCA, in effect removing the constraints of the LCA on fires deep root, would allow the co-evolution of climates, habitats (of which wildfire is an integral part of many) and hominoids to be considered within a new and less restricted framework. By the late Oligocene apelike primates had appeared and thrived into the Miocene as tropical forest inhabitants (Stevens et al. 2013, Crompton 2015). By the late Miocene (~15- 12Ma) major climatic changes (mainly cooling and drying) had been put into effect by the vast expansion of Antarctic ice-sheets leading to changes in habitat concomitant with the evolution of new primate niches (Crompton 2015). The Late Miocene fossil record is relatively rich (Moya-Sola and Kohler 1996, Chaimanee et al. 2003) supporting the notion of rapidly changing Miocene niches (Crompton 2015). A split between gorillines (and their fossil relatives) (e.g. *Chororapithecus*, ~10.5 Ma [Suwa et al. 2007]), and chimpanzees, bonobos and humans (and their fossil relatives) occurred during the last stages of the Miocene, possibly in the Tortonian (11.62Ma – 7.246Ma) or Messinian (7.246Ma – 5.333 Ma) (Crompton 2015 - but see Crompton 2015 for a review of crown hominin palaeontological evidence).

When and where the psychological mechanisms required to utilise Mode 1 fire-use were adopted is open to conjecture (perhaps experimental cross-species comparisons of extant ape reactions to fire and/or smoke could greatly aid researchers here), but once tropical forest was replaced over large areas of Africa by more open habitats which invite fire in (e.g. lightly wooded bush or savannah grasslands) opportunities to view the effects of fire and interact with fire would have markedly increased (Gowlett 2016). This increase in the frequency of Wildfire Package interaction would have allowed opportunities for experimentation with different responses to fire but it can also be modelled as generating increased selection pressures for the emergence of new relationships with fire, including altered psychological and physical reactions, to appear and stabilise.

As fire has a very poor preservation potential in the archaeological record the emphasis of previous researchers has been focused on either archaeological excavations trying to identify primary evidence for fire within the era of *Homo* or on analyses of hominin morphology and explanations based thereon. Evidence of hominin fire-use in the period 1-2 Ma has gained so little traction amongst the research community so why push the idea of hominin fire interactions back another 3-5 MA? There has thus been little need to invoke a deep root of fire back to the LCA or beyond (but see Burton 2009). Analyses of the behaviour and particularly the psychology of the LCA are almost impossible to undertake due to a simple lack of evidence, and would lack credibility if undertaken. If this debate were no longer to be constrained by the limiting factor of the LCA then this creates a large amount of evolutionary space during which adaptations to hominin psychology or Landscapes of Fear (see Chapter 4) may have occurred. This line of thinking is similar to that taken by Burton (2009), who believes that the very act of associating with fire was the turning point in human evolution. Due to the lack of evidence for primate fire-use or primate fire interactions the initial psychological transition to a closer, less fearful, relationship with fire is assumed to occur long after LCA. Even the 'Pyrophilic Primate Hypothesis' (Parker et al. 2016 – discussed in detail in Chapter 3), which proposes a central role for fire-use as a pivotal Late Pliocene evolutionary driving force for *Homo*, is supported by the statement that:

"*Given the frequency of burning in sub-Saharan Africa, many plants and animals have adapted to cope with and even benefit from fire. We suggest that the bipedal ancestors of our genus that inhabited tropical Africa 3.6 to 1.4 MA did as well*." (Parker et al. 2016; 56)

If fire-use is viewed as a human apomorphy/autapomorphy it requires no deep root. However if humans are not viewed as 'unique pyrophiles' then different perspectives are possible; many creatures (animals, birds and insects included) have learnt how to benefit from the presence and impacts of fire (Bouwman and Hoffman 2007, Herzog et al. 2016, Pyne 2016). It may be that humans have simply developed this relationship further as they have done with language and lithic tools use.

As anthropogenic fire is only recognised by all researchers as occurring within the last half million years (Roetbroeks and Villa 2011) there appears little need to invoke a very deep root for fire. One objective of this study is to provide a different perspective to the onset of hominin fire-use being somehow linked to the onset of archaeological visibility of this behaviour. While the paleontological and archaeological records constitute the only direct evidence of temporal change in morphology and behaviour; in the absence of archaeological or fossil evidence perhaps ethological evidence can support the idea of a very deep root to hominin fire behaviour. In this study the case is presented and discussed that, supported by observations from chimpanzees and other primates in the wild allied with research on captive chimpanzees, a range of alternative perspectives of hominin fires root appear plausible.
Now two different scenarios or 'thought models' are laid out. These scenarios should be viewed as 'different ends of a spectrum' with other viable possibilities existing. In this study no preference is made between the two; however it seems of great importance to this thesis to highlight and discuss the evidence that supports these different scenarios.

'The ancestral risk averse to fire' scenario

One way of hypothesising the ('pre-Mode 1') relationship with fire of the 'last common ancestor of *Homo* and *Pan'* (LCA) and immediate antecedents is that it would have been distinctly 'risk averse' due to the many dangers of fire (e.g. smoke inhalation, heat and flames). Fire frequency in the dense tropical Oligocene forests (the evolutionary environment of crown hominins) can (by using principals of uniformitarianism) be surmised as being very low and not necessarily experienced by each generation. As very little specific information of the LCA is known (Sherwood et al. 2008, White et al. 2015) (albeit that White et al. 2015 proposed that *Ardipithecus* provides strong evidence that the LCA was a generalized African ape), including the specific kind of environments inhabited, the wildfire frequency experienced by the LCA is incredibly difficult to model. Very low fire frequency would create insufficient opportunities to become familiar with fire. As apes are 'K' strategists and cannot afford the high costs of mortality (Lovejoy 1981, Foley 2001), being risk averse in the presence of fire seems an appropriate response; hence ***the ancestral risk averse to fire*** scenario. As is the case with predator avoidance mechanisms it would be expected that certain sensory aspects of wildfire (noise, heat, smoke, smell, intense light and cues gained from the response of other creatures) would trigger 'risk-averse' behavioural responses.

When analysing the putative ancestral relationship between fire and hominins with a landscape-level perspective, being 'risk averse' to fire requires hard-wired inherited psychological mechanisms to direct behaviour in 'risk averse' ways, (e.g. flight). Flight however can take many forms: e.g. controlled evacuations or blind panic. Within the 'ancestral risk averse to fire' scenario adaptations would have to have emerged and evolved to enable the perception of fire 'as a nexus of risk' to become a perception of fire as an 'opportunity, tool, or resource to be exploited'. These changes can be framed as occurring in times of wide climatic variability that has been identified as suiting generalists (Potts 1998) or versatilists (Potts and Faith 2015). Potts (2012) suggested that a recurrent theme in hominin evolution is adaptability in response to environmental uncertainty; this adaptability must have included psychological as well as physical and behavioural adaptations. Increasing availability of wildfire on the landscape allied to resource stress in more traditional resources would provide an appropriate platform for heightened behavioural plasticity and behavioural innovation, which the hominin brain appears uniquely adapted for (Sherwood et al. 2008).

If the ancestral state was 'risk averse' then before hominins could become effective fire-users at the very least this framing of fire as 'a danger to be avoided' needed to be overcome. Cognitive self-control based on sophisticated environmental understanding would be needed to inhibit automatic responses (Sherwood et al. 2008). Underlying psychological adaptations would be required as a precursor to the development and proliferation of complex fire-use (Twomey 2013). Within the 'ancestral risk averse to fire' scenario psychological changes allied with ensuing bio-chemical adaptations within the hominin brain would be needed to enable the relationship with fire to transition from the modelled pyrophobic or 'very wary' relationship with fire to, by the arrival of modern humans, become a very strong attraction to aspects of the Wildfire Package. Over the course of evolutionary time as hominin fire interactions increased and became ever more complex and diverse (with the sum of the net benefits of this association also increasing) then it is proposed here, in tandem, the nature of inherited psychological mechanisms would shift to an 'ever more positive framing of fire'.

This may not have been a smooth process, indeed it's entirely plausible that positive psychological adaptations emerged a number of times in different populations before eventually becoming fixed. The period from 4-3.5Ma, suggested by Burton (2009) during which a large-scale radiation occurs within the ancestral group and includes gracile and robust australopiths (actual species numbers depend on either a 'lumping' or a 'splitting perspective'), and during which distinct dietary changes are visible (Sponheimer et al. 2013, Levin et al. 2015), links well with this transition from an ancestral risk averse state. Burton (2009) highlights the behavioural plasticity of this period as well as the fact that 'sufficient evidence' has been excavated to infer behaviour and lifeways thus enabling researchers to construct theories and models.

'The very ancient awareness of the properties and affordances of fire' scenario

In this study the topic of fires deep root is of central, vital importance, and cannot be ignored and so the 'very ancient awareness of the properties and affordances of fire' scenario is here proposed to counter the 'ancestral risk averse to fire' scenario (although in effect they should be seen as 'end-spectrum' ideas rather than two discrete choices). This scenario is based on the premise that primates of all kinds are intelligent foragers (irrespective of relative brain size). In environments where fire is relatively frequent Wildfire Package affordances will offer fitness benefits of interest to primate foragers. The 'very ancient awareness of the properties and affordances of fire' scenario does not suggest that utilisation of the Wildfire Package is synapomorphic for all primates but that instead appropriate psychological responses to fire may have arisen many times over geological time when specifically relevant to individual lineages (i.e. when sufficient adaptive selective pay-offs are attainable and when fire frequency is sufficiently high). However, due to the very close genetic relationship between *Pan* and *Homo* (more than 99% of non-synonymous DNA sequence similarity is shared [Wildman et al. 2003]) the 'very ancient awareness of the properties and affordances of fire' scenario predicts that, with respect to hominins, recognition of the behaviour of fire is very ancient and may even predate the LCA. This is in line with Burton's (2009) suggestion that familiarity with fire was beginning to take place as humans and apes diverged.

Depending on how each researcher views the lower limits of Mode 1, the 'very ancient awareness of the properties and affordances of fire' scenario can be construed as incorporating the very deepest roots of anthropogenic fire-use. However in this study the 'awareness of the properties and impacts of fire' are not classed as Mode 1 fire-use until they are *deliberately* and *preferentially* sought and used. Due to a lack of archaeological evidence (for reasons discussed previously) this scenario is supported here by ethological evidence (see previously discussed limitations of this approach). On a cautionary note, it is once again noted here that parallelism is common in anthropoid primates (White et al. 2015). In addition to the work of Pruetz and LaDuke (2010), who published their personal observations on the reaction of a group of wild chimpanzees to a wildfire, other papers have recently been published that expand on the cognitive and technological capacities of extant great apes. For example vocal fold control beyond the species-specific repertoire of orang-utans (Lameira et al. 2016) which is critical to the evolution of language, as well as the cognitive capacities for cooking in *Pan troglodytes* (Warneken and Rosati 2015).

Studies on extant primates (discussed in detail over the next few pages) allied with knowledge gained from the expansion of ethoarchaeology (e.g. Mercader et al. 2002, 2007, Carvalho et al. 2008, Haslam et al. 2009, Hernandez-Aguilar 2009) have demonstrated that perhaps more shared traits exist between *Homo* and great apes pertinent to adaptations previously ascribed solely to hominins. Indeed Lewis and Harmand (2016; 6) considered the possibility when attempting to explain Lomekwian material that: "*stone tool making might not be unique to the hominin lineage; all great apes and their ancestors might have* *developed this ability. The LOM3 tools could have been made by any hominoid around at the time, and the ability has been lost in the lineages leading to the living great apes*". Although they rejected this theory on the grounds of parsimony, what this does show is that were a deep root to be postulated for fire by researchers that penetrated all the way back to the LCA (and potentially beyond) it might not be as outlandish an idea now as a decade ago.

In this study the stance taken is that many paradigms created in the 1960s, 70s, 80s and even the 1990s need to be challenged and should not necessarily constrain current thinking and research. It should no longer be seen as mere fancy to suggest a very deep root of hominin fire-use. The idea should at least be contemplated that hominin fire interactions were 'part of the background' to the adaptations and behaviours belonging to the diverse group of 'bush-country apes' that make up the hominin clade (Gowlett 2016); hence the development of the 'very ancient awareness of the properties and affordances of fire' scenario. When the 'background' came to the 'foreground' is an obvious area for close scrutiny but it appears that thus far the 'background' has been largely ignored; this is perhaps due to an inability to generate high quality data with available methodologies.

Chimpanzees and fire

Given the subject matter approached in this study it is relevant to briefly summarise the characteristics of wild chimpanzees (*Pan troglodytes*) that could support a very deep root of fire behaviour and perhaps provide evidence of synapomorphy. Recent observations from West Africa by Pruetz and LaDuke (2010) on the interactions between fire and *Pan* suggest the idea that very simple and rudimentary relationships between hominins and fire may stretch back further in time than currently supposed. Mosaic-habitat inhabiting chimpanzees were observed calmly monitoring bush fires at close range and modifying their behaviour in reaction to the fire. Pruetz and LaDuke (2010: 648) even state that they consider the chimpanzees behaviour to be '*predictive rather than responsive*' and lacking in stress or fear. Unfamiliar vocalisations were heard (the first such recorded in more than 2300 contact hours) and exaggerated displays were performed by the dominant male. Chimpanzees were seen to anticipate the fire's movement and adapt their behaviour accordingly, seeming unconcerned at distances from the fire that '*made observers uncomfortable*' (Pruetz and LaDuke 2010: 648); anticipation of the fire would require rudimentary versions of complex cognitive capacities (e.g. response inhibition and anticipatory planning [as per Twomey 2011]).

While accepting that the chimpanzee behaviour observed at Fongoli has within published literature not been corroborated by being observed again, and thus is not proven for all *Pan troglodytes*, the observations of Pruetz and LaDuke (2010) suggest that the initial onset of the development of appropriate psychological mechanisms may go back as far, or even predate, the LCA. Further Panin ethological evidence, observational and experimental, is required to corroborate, support or dismiss this theory. Pruetz and LaDuke's (2010) observations are supported by recent experimental work demonstrating that chimpanzees possess the domain-general cognitive skills needed to cook (Warneken and Rosati 2015); results showed that chimpanzees also actually prefer to eat cooked foods. *Pan troglodytes* have been previously identified to have rich behavioural complexity (Whiten et al. 1999), habitual tool use (Haslam et al. 2009) and diverse material culture (McGrew 2004) passed down through generations by social learning (Carvalho et al. 2008). These until fairly recently were all considered the sole domain of humans (Sayers and Lovejoy 2008) in the same way that fire is now.

While acknowledging from the outset that the observations by Pruetz and LaDuke (2010) are merely observations of one group of chimps interacting with one incidence of fire, they are the only such published observations and as such have some limited use. Here they are used as evidence to generate two alternative explanations:

i) hominins 5-7 million years ago possessed a basic conscious awareness of the nature, movement and impacts of wildfire (as per Atwell et al. 2015)

ii) homoplasy (convergent evolution) has occurred and *Panins*, with respect to fire, have taken a similar (or parallel) evolutionary trajectory to *Homo* (although not as well developed) and have independently developed an awareness of the behaviour of wildfire and the psychological mechanisms to cope with its close presence; this may be a very recent phenomenon

The first explanation basically describes a very deeply rooted hominin relationship with fire. Relative to the second explanation, an anthropogenic spike in African fire frequency in the Holocene (observable in the 'elemental carbon' record - elemental carbon acts as a proxy for wind-blown combustion debris [Bird and Cali 1998]) may have provided the conditions for certain chimpanzee populations to very recently adapt their behaviour around fire.

Pruetz and LaDuke (2010: 647) state that at Fongoli (the study site) "*wildfires are set yearly by humans for land clearing and hunting, and most areas within the Fongoli chimpanzee home range experience burning to some degree*". Therefore at Fongoli encounters with annual anthropogenically ignited fires may have led to the very recent evolution of observed reactions and behaviours. Could frequent interactions with fire have produced such rapid distinct changes in panin psychology and behaviour that Pruetz and LaDuke (2010) would suggest their observations to be evidence of a hominoid synapomorphy? The only way to test whether the observations recorded by Pruetz and LaDuke (2010) holdfast across all populations or are unique to specific (West African) chimpanzee populations would be to observe different wild populations reactions to, and behaviour around, wildfire. This may take some considerable time for many reasons, not least because of the low fire frequency in some environments hosting chimpanzee populations.

Phylogenetecists have posited that as chimpanzees and humans both use tools the most parsimonious conclusion is that the LCA of *Pan* and *Homo* must have been a tool-user (Haslam et al. 2009); in effect arguing that tool use is a synapomorphy. This suggestion could also be extended to psychological relationships with fire (i.e. an awareness of the properties, characteristics and behaviour of fire); albeit humans have advanced far beyond chimpanzees in the same way that they have with tool use. An awareness of the properties, characteristics and behaviour of fire must surely be the precursor to a closer relationship with fire. Without effective strategies to minimise the risks associated with wildfire and wildfire burnt environments the potential costs associated with a close relationship with fire can be viewed as grossly exceeding the potential benefits. At some point effective psychological mechanisms must have evolved; the evolution of which must be viewed as a key stage in the transition to anthropological fire.

Monkeys and fire

The behaviour of monkeys is useful to the reconstruction of the mentality of ancient hominins (Burton 2009). Further evidence for a deep root of fire comes from observations on Vervet monkeys (*Chlorocebus aethiops*) including those made in the Soetdoring nature reserve in South Africa as part of this study. Vervet monkeys were observed feeding (and investing in vigilance) in wildfire burnt environments (Photos A and B) very recently after a fire (within five days of initial ignition), suggesting that psychological mechanisms and understanding of fire behaviour may also be present in that genus. These personal observations are backed up

Photo A: Vervet monkeys (*Chlorocebus aethiops*) foraging and investing in vigilance on a wildfire burnt environment at Soetdoring nature reserve (SA) in 2012 (Photo courtesy Maryjka Blaszczyk)

Photo B: A Vervet monkey (*Chlorocebus aethiops*) preferentially foraging on a wildfire burnt environment at Soetdoring nature reserve (SA) in 2012 (Photo courtesy Maryjka Blaszczyk)

Species	Type of interaction	Reference
Cercopithecus aethiops	Travel through burn	Jaffe and Isbell (2009)
	Foraging in burn	Jaffe and Isbell (2009)
Cercopithecus sabaeus	Consumption of cooked seeds	Harrison (1983a, 1984)
Macaca fascicularis	Foraging in burn	Berenstain (1986)
	Consumption of cooked fruit	Berenstain (1986)
Macaca mulatta	Consumption of cooked fruit	Armelagos (2010)
Pan troglodytes verus	Fire tolerance	Pruetz and LaDuke (2010)
	Consumption of cooked fruit	Brewer (1978)
	Consumption of cooked fruit	S. Bogart, personal communication
	Travel through burn	J. Pruetz, personal communication
Papio Anubis	Foraging in burn	K. Hunt, personal communication
Papio cynocephalus	Range expansion in burn	Rasmussen (1983)
Papio ursinus	Foraging in burn	J. Beehner, personal communication
	Foraging in burn	L. Swedell, personal communication
Symphalangus syndactylus	Range constriction postburn, habitat deterioration	O'Brien et al. (2003)

Table 2.3: Published and anecdotal post hoc primate fire interaction (from Herzog et al. 2014)

with observations and studies within the literature. Like humans and chimpanzees, vervets are highly omnivorous; a dietary strategy that links well with foraging in wildfire burnt environments due to the broad range of potentially available Wildfire Package Affordances.

Similar to the observations in chimpanzees published by Pruetz and LaDuke (2010), when Vervet monkeys have been observed in the vicinity of slowly spreading wildfires the response witnessed by researchers was not to flee but instead to avoid the path of the fire (Herzog et al. 2014, 2016); the troop was '*seemingly unbothered by its approach*' (Herzog et al. 2014: P554). Herzog et al. (2014) also observed that after the fire had extinguished, the newly burnt environment was incorporated into the home range of the troop whereas previously it had not been used (this maybe be in part connected to the significantly improved encounter rates for invertebrates and grasses in recently burned landscapes identified by Herzog et al. [2016]). A 'wildfire driven range expansion' has also been previously observed in omnivorous Yellow Baboons (Rasmussen 1983) (Table. 2.3.). Additionally Borneon lion-tailed macaques have been identified to preferentially utilise burnt environments in times of resource stress (Berenstain 1986); these observations show the clear realisation that a range of monkey species have of Wildfire Package opportunities. The idea of a wildfire driven range expansion is especially useful as, when looked upon from purely a dietary perspective the Wildfire Package may not provide sufficient selective advantage; Herzog et al.

(2016:432) found that for Vervets while encounter rates improved postencounter profitabilities in burned patches were not significantly different from unburned data.

Of particular relevance to this study Herzog et al. (2014:555) made two important statements:

i) *Observations highlight the opportunistic behaviour of primates around fire and suggest a pattern of tolerance, interest, and even exploitation of burned landscapes*.

ii) *Vervet monkeys will take advantage of landscape fires by altering their spatial patterns to incorporate newly burned areas* – (A behaviour previously observed in the same species by Enstam-Jaffe and Isbell 2009).

Herzog et al. (2014: 555) go on to specifically state that their results '*help characterize primate-wide adaptations to fire-modified landscapes that should guide hypotheses about the use and control of fire by our own ancestors*'. In line with the evidence and reasoning presented by Herzog et al. (2014) it can be argued that Pliocene hominins would have been capable of the same kind of behavioural flexibility, potentially to an even greater degree due to greater cognitive complexity and 'pre-existing cultural capacity'.

Enstam-Jaffe and Isbell (2009) and Herzog et al.'s (2014: 559) descriptions of primates' exploitation of burned landscapes provide strong evidence that non-hominoid primates are able to understand the behaviour and nature of fire and are able to make attendant behavioural changes to travel and foraging opportunities due to the presence of fire on the landscape. However their contention that: "*even the most terrestrially constrained of savanna-dwelling primates expansion into burned territory suggests a deep phylogenetic history of fire tolerance and pyrophilic tendencies*" is not fully supported in this study. The idea that fire's deep root (in the form of fire awareness not fire-use) goes back to the LCA of

Pan, *Homo* **and** *Chlorocebus* is a step too far and is not proposed here. Pruetz and LaDuke's (2010) argument for a synapomorphy within the human–chimpanzee clade is assessed in this study as 'reasonable to an extent', but any idea that this can be expanded to create a clade large enough to include *Chlorocebus* is not evidentially supported and is regarded as 'insufficiently plausible'.

Enstam-Jaffe and Isbell (2009) and Herzog et al.'s (2014 and 2016) work emphasises the possibility that selective forces, when sufficiently beneficial, can drive adaptations to appear. While observations by Herzog et al. (2014: 559) highlight the '*deep phylogenetic history of fire tolerance and pyrophilic tendencies*' required for fire's deep root, they perhaps more importantly also clearly highlight the fact that (even) small brained omnivorous primates are aware of the benefits of wildfire burnt environments and resources and will adapt life strategies to take advantage of these opportunities. Pertinent to this study, Herzog et al. 2014 (P554) specifically also point out that their results "*expose deficiencies in our knowledge of fire-related behavioural responses in the primate lineage and highlight the need for further investigation of these responses as they relate to foraging opportunities, migration, resource use, and especially fire-centric adaptations in our own genus*".

Gorillines and fire

As a way of constraining the timing of the 'very ancient awareness of the properties and affordances of fire' scenario the behaviour of extant gorillines is also assessed. A detailed literature search unearthed no evidence of published interactions between gorillines and wildfire. In the absence of any evidence that extant gorillines have the same psychological relationship with or understanding of fire as suggested for chimpanzees both by Pruetz and LaDuke (2010) and Warneken and Rosati (2015) then it is proposed here that the absence of evidence should be taken as evidence of absence based on the following observations.

Current gorilla environments tend to have very low natural fire frequency (acknowledging that what we see nowadays are just tiny 'refugia' habitats, even 150 years ago gorilla habitation ranges were much wider). While on research in Mgahinga National Park (inhabited by a population of *Gorilla gorilla berengei*) in Uganda in 2015 as part of this study, a ranger (Twjwamuleba John) with a 30-year association with the park was informally interviewed around a campfire at the summit of Mt Sabinyo. He was certain that all instances of significant wildfire in this park during his period of tenure (N=5) were anthropogenically ignited (honey hunters and charcoal burners being the main agents) (Twjwamuleba John Pers. Comm.) and remembers no evidence of (any) gorillas being interested in any aspect of the Wildfire Package. Contrasting this, a number of anecdotes were told of personally witnessed innovative gorilla tool-use related to collecting honey and crossing flooded streams.

Given no evidence exists in the literature, nor within the oral testimony provided by Mr. Twjwamuleba, for any sort of gorilla fire interactions (allied to the fact that gorillas are not generalists and are extremely highly adapted to their environments which contain significantly low levels of wildfire due to amongst other factors high precipitation levels and altitude), then the most appropriate assessment to make is that the required driving forces for the presence of psychological adaptations to fire do not currently exist for gorillas, and probably have not done so in the past. With fire being of very low frequency there is no case to argue for any selection pressure for fire adaptation in extant gorillines other than perhaps a cautious and risk-averse response if wildfire is confronted. As well as the lack of evidence for fire association with gorillines, a comprehensive literature search has also failed to find any evidence for fire associated behaviour with Pongids (see also Table. 2.3) despite the fact that Borneo and Sumatra have recently experienced large-scale annual burns; some of which, like those associated with the El Nino of 1997/1998, were of truly gargantuan proportions.

Ancient palaeoenvironments

Broadly the Late Pliocene and Early Pleistocene should be viewed as a time when local, continental and global climatic factors were significantly evolving which would have enabled the destruction (or stimulated the adaptation) of old niches and the creation of new ones (with potentially significantly altered natural fire regimes); a period suited to behaviourally plastic generalists (Potts 1998). Behavioural plasticity can be expected to be high while a new niche is being constructed and colonised (Mobbs et al. 2015), otherwise how could the new niche be built. This would be especially true when the new niche is significantly different from previous niches; as is the case when the niche of *Ardipithecus* is compared to the niche of *Australopithecus* (White et al. 2015), suggested to have been a relatively rapid shift (White et al. 2006). Compared to *Ar. ramidus*, Australopithecines had roughly 25% larger cranial capacity, which can be linked to novel adaptive behaviours changing social structures and/or new neural circuitry (White et al. 2015)[9]. This is the kind of background information that suggests the kind of evolutionarily significant landscape-use transition proposed by FAF (outlined in Chapter 4).

Increasing encephalisation can be linked with greater cognitive complexity. Ancient hominin neuroanatomical substrates would have contributed to the enhancement of behavioural flexibility and social cognition (Sherwood et al. 2008). It is here proposed that increasingly intelligent and perceptive hominins would identify, observe and react to the behaviour of predators and other risk factors and construct appropriate risk-reductive and minimisation responses. This process may have started with any of the diverse group of hominins that make up the lineage between the LCA and early *Homo* (hypothetically including the LCA

[9] No clear proof exists that *Ardipithecus* definitely evolved into *Australopithecus.* The possibility exists that one rapidly replaced the other (White et al. 2015)

itself); although it is most likely to have accelerated once a more terrestrial niche was occupied by later Australopiths at ~3.5Ma. An analysis of some macro-scale palaeoenvironmental reconstructions suggest that within the time period between the LCA and *Homo* numerous opportunities would have presented themselves for behavioural plasticity to be high and novel behaviours trialled and, if sufficient adaptive pay-offs accrued, stabilised within populations (e.g. Figs 2.5 and 2.6). A key question is whether we currently have sufficient grasp of the form and nature of ancient hominin niches to be able to coherently model behavioural changes. Palaeoenvironmental reconstructions are one important way for researchers to assess the nature of ancient niches.

Can Palaeoenvironmental reconstructions adequately inform researchers?

Macro-scale palaeoenvironmental reconstructions created from a number of proxies, (including analysis of different isotopic signals recovered from different sources [Figs. 2.5 and 2.6]), suggest a long-term continental trend of cooling and drying in Africa over the last 4Ma that appears to have driven the fragmentation of rich woodland environments and thus spatial and temporal reductions in certain resources (deMenocal 2004 *Passim*, Trauth et al. 2007 *Passim*, Levin et al. 2011, Bibi et al. 2013, Plummer et al. 2015).

This process would have created adaptive selective pressures leading to genetic selection, adaptation and innovation (deMenocal 2004). For example, reduced forest cover increases the risk from terrestrial predators (Winder et al. 2013) and would then lead to strong selective pressure for new anti-predations strategies that would be able to cope with predators without resorting to the refuge of trees; creating significant LOF impacts. Impacts of the aridification of African habitats included the spread of grassland/ bushland biomes and fragmentation of

Fig 2.5: Temporal relations between changes in African Climate and forcing, East African vegetation, glacial ice volume and hominin evolution. At least two distinct hominin lineages (*Paranthropus* and *Homo)* emerge from a single ancestral line (between 3.0 and 2.5Ma) (from deMenocal 2004)

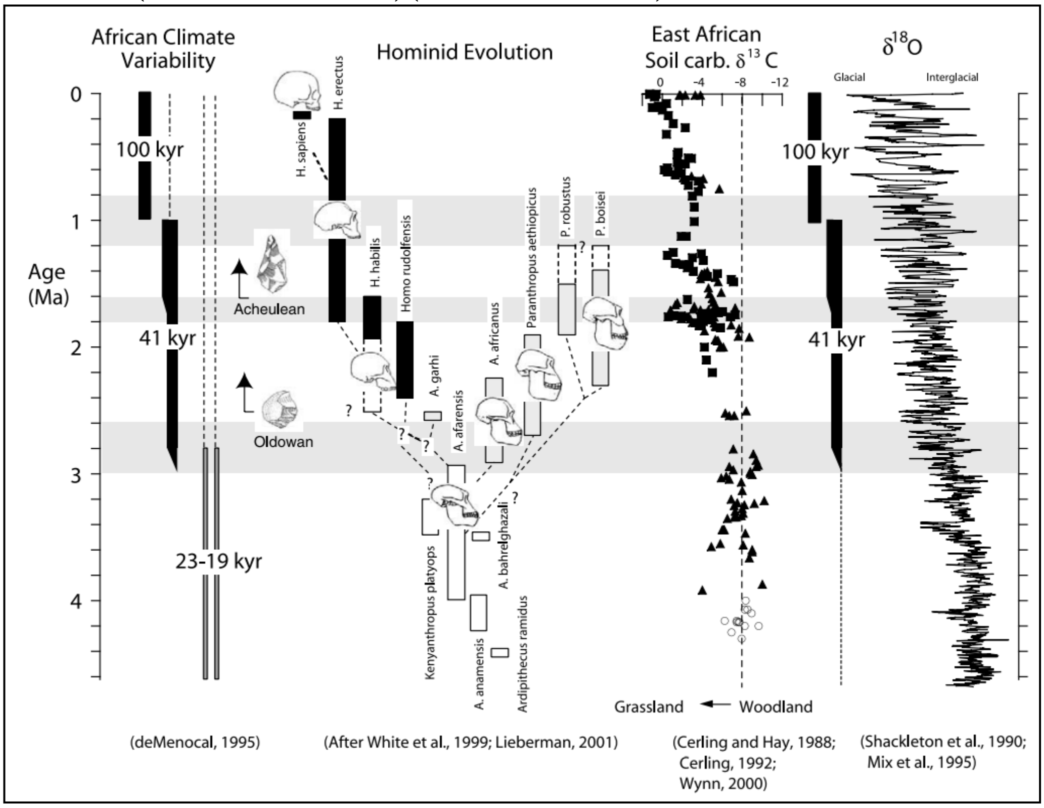
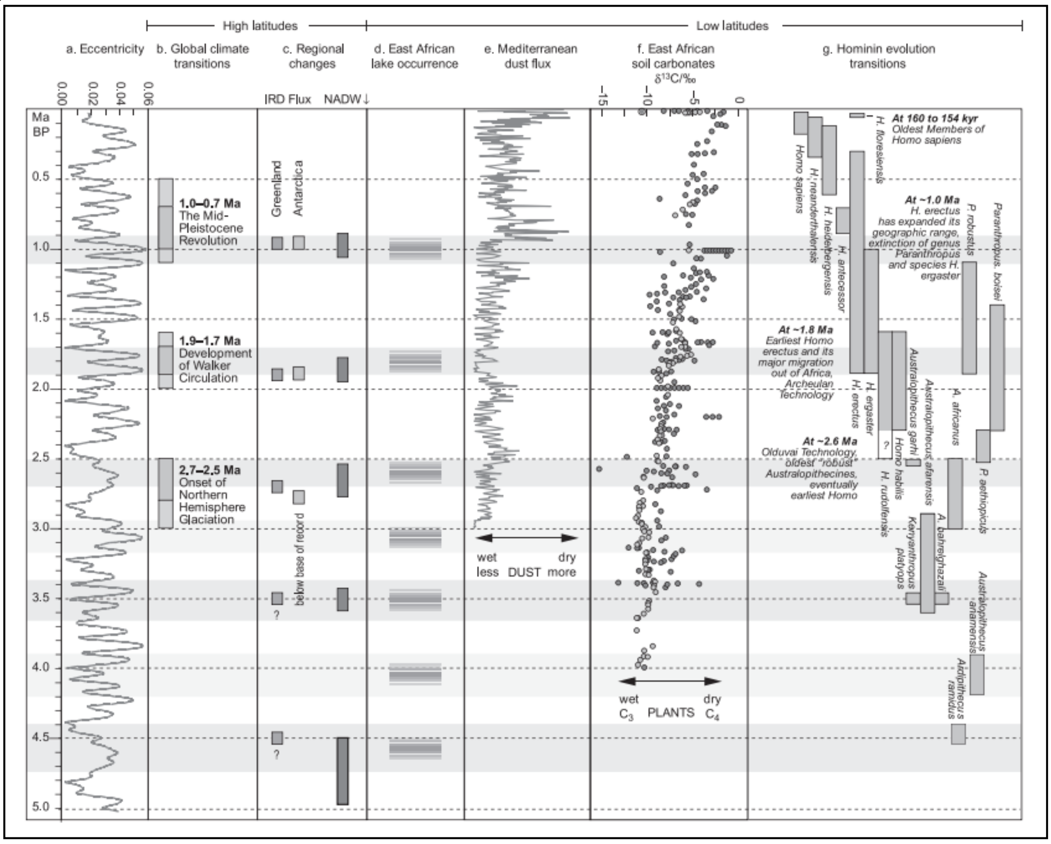


Fig 2.6: A comparison of eccentricity variations with high-latitude climate transitions, Mediterranean dust flux, soil carbonate carbon isotopes, East African lake occurrence, and hominin evolution. (From Trauth et al. 2007 *passim*)

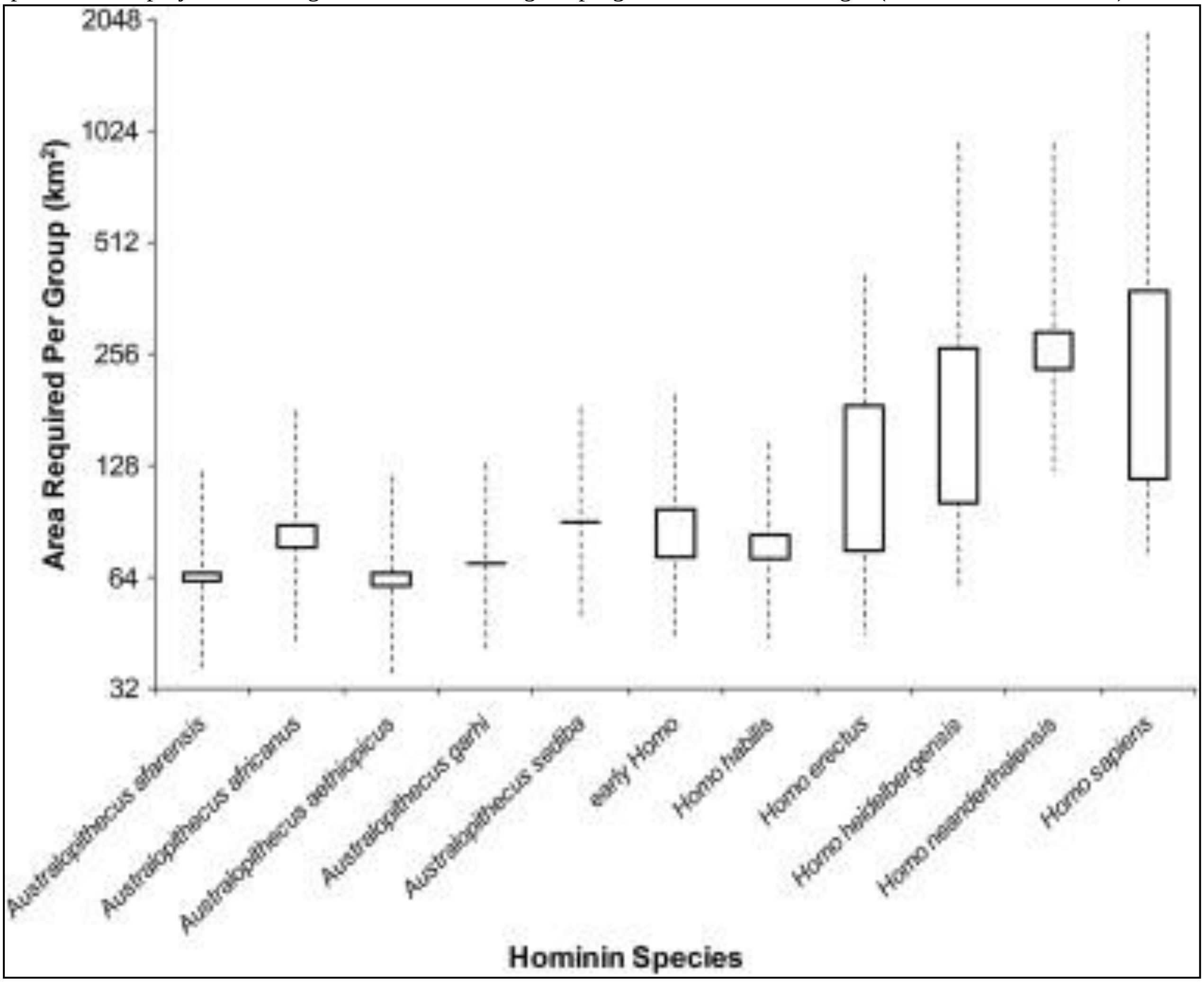


woodland habitats; the biome reconstructed for both *Ardipithecus* (White et al. 2014) and more recently, and perhaps controversially, *Australopithecus afarensis* (Kappelman et al. 2016). Reductions in resource density and fragmentation of habitat introduce a new suite of adaptive selective pressures directing evolution in new directions.

As an example of this one way to adapt to mitigate resource scarcity is to increase range sizes (Grove et al. 2012); a pattern identified in the hominin fossil record (Grove et al. 2012 - Fig 2.7) and also in savannah chimpanzees at Ugalla (TZ) and Semliki (UG) (Piel et al. 2015). Increased range sizes in turn required more efficient locomotion and possibly the deployment of different social strategies such as fission-fusion; a strategy which affords individuals the benefits of gregarious living, including defence from predators, and the opportunity to locate widely distributed foods, while simultaneously minimising competition over resources (Goodall 1986, Sherwood et al. 2008). Less arboreality could also explain increased selection for bipedal behavioural and morphological adaptations. Changes in physical environments would also lead to changes and adaptations in mental environments including landscapes of fear. Resource scarcity could also promote exploitation of certain Wildfire Package foraging affordances. Periods when strong resource acquisition adaptive selective forces may be generated would be in times of resource stress or reducing levels of primary productivity, potentially deducible from proxy data (Fig. 2.5).

Climatic trends of cooling and drying can be modelled as resulting in increased aridity (observed through the first appearance of many arid-adapted bovids [deMenocal 2004, Plummer et al. 2015]) and increased occurrences of wildfire, particularly in areas where wildfire prevalent grassland biomes had supplanted or replaced woodland biomes. Acute resource scarcity would strengthen adaptive selective forces towards balancing energy cards at ‘bottleneck’ periods of (seasonal?) shortage. One way to increase the strength of the proposed adaptive selective forces generated by early fire hypotheses is to model utilisation of the Wildfire Package as an ‘ecological need’, or necessity, rather than an optional strategy. Environmental pressures may have forced ancient hominins to change their behaviour so as to be able to use more risky and peripheral habitats, to live in larger groups, or to use novel resources (Shultz et al. 2012). While it is not the position of this study to state that exploitation of the Wildfire Package was definitely an ecological need and the only way that certain communities could have sustained themselves at specific resource stressed times, it may be highly informative to highlight the potential strength of adaptive selective pay-off that this scenario highlights.

Figure 2.7: Averaged area per group requirements for the ‘lumping taxonomy’ employed in Grove et al. 2012; species are displayed according to a broad chronological progression from left to right (from Grove et al. 2012).



One way of summarising the available data would be to conclude that combined long-term trends of increasing C_4 grasslands (more frequent burns) and increasing bipedality (wider ranges) provided the ideal conditions for increasing amounts of interactions with natural wildfires (Bobe 2006; Atwell et al. 2015), resulting in lots of possibility for fire-use to be incorporated into the hominin toolkit. It is worth reiterating here that familiarity is a required necessary precondition for any emergent fire behaviour (as per Atwell et al. 2015); interactions with fire would need to become normalised so that the myriad of possible uses and benefits of close interactions with fire and wildfire burnt environments can be ascertained, trialled and eventually incorporated into toolkits.

This use of macro-scale palaeoenvironmental reconstructions appears to have obvious merit especially when looking at broad hominin evolutionary changes however it is imperative to consider the robustness and precision of available palaeoenvironmental reconstructions at both the macro- and micro- (e.g. site specific) scale. If the information provided from palaeoenvironmental analysis is implicitly accepted then it is an obvious conclusion to reach that should be viewed as an incredibly useful tool for helping paleoanthropologists understand and model explanations for archaeologically observable trends.

On one level the understanding of biological responses to climatic changes in the fossil record hinges upon the ability to distinguish the effects of large-scale climatic signals from the effects of, amongst other things, taphonomic processes and collection biases (as per Bobe et al. 2002). However in this study the question of the degree of resolution of the palaeoenvironmental record seems to also be incredibly important. From a perspective of early fire researchers the kinds of palaeoenvironmental resolution that would be useful would be on a seasonal or annual scale (here even a decadal analysis would be classed as 'fine-scale') so that a high quality and relevant assessment of ancient fire regimes could be undertaken. Palaeoenvironmental researchers however seem to have a completely different definition of 'fine-scale'; for example Bobe et al. (2002:476) consider changes in taxonomic abundance patterns to be 'fine-scale' with a chronostratigraphic resolution of $<10^4$ years.

It is suggested here that, on a macro- and micro- scale, the current precision of palaeoenvironmental analysis is not sufficiently good enough to be implicitly accepted beyond the broadest trends. Late Pliocene climatic changes have previously been implicated in environmental changes and hominin evolution (Bibi et al. 2012); but studies may have been impacted by poor techniques and poor sampling. Additionally, from a perspective of viewing hominin evolution, macro-scale (e.g. continental scale) analyses (and the patterns and trends deduced from them) do not sufficiently incorporate local conditions (e.g. microclimates and altitude) to be overly useful when discussing Plio-Pleistocene ancient hominins as from current analyses it does not appear that Plio-Pleistocene ancient hominins were living in particularly large or dense populations. It may have been that, to enable successful exploitation, ancient hominins had niches that required a specific set of environmental conditions which may have been very present on very local scales (Bobe et al. 2002); ecologically autonomous regions will have existed in Plio-Pleistocene Africa almost entirely dependent on local conditions (Bobe et al. 2002, Bibi et al. 2012). Many palaeoenvironmental reconstructions available in the literature should be viewed as being able to provide general trends and patterns that can be highly informative to researchers; however, as argued by Winder et al. (2013) both the accuracy and limitations of micro and macro scale palaeoenvironmental reconstructions need to be clearly realised.

To clearly highlight the stance on palaeoenvironmental reconstructions taken in this study (and to show that 'a trick has not been missed' by not focussing on this approach) two case studies are assessed; the 'Savannahstan Hypothesis' (as proposed by Dennell and Roebroeks 2005) as an example of a macro-scale palaeoenvironmental reconstruction, and the Omo-Turkana basin (including the Shungura formation) which has been extremely heavily palaeoenvironmentally surveyed since the 1960s by (amongst others) three different teams (French, American and Kenyan) from the International Omo Research Expedition (Bobe et al. 2002, Plummer et al. 2015) as an example of an in-depth site-specific study.

The Savannahstan palaeoclimatic reconstruction

One particular large-scale palaeoenvironmental reconstruction that has been proposed is the idea of Savannahstan. 'Savannahstan' as a concept was first published by Dennelll and Roebroeks (2005) as a way of reframing the existing Africa or Asia debate, although supporting hypotheses and ideas had previously been introduced by Robin Dennell (Dennell 2004). Dennell and Roebroeks (2005) make the case that Africa and Asia should not be seen as separate continents as a terrestrial land bridge exists in the form of the Arabian Peninsula. They see the dichotomy of Asia and Africa as part of Western society's Graeco-Roman heritage that the processes driving species migration and floral and faunal interchange (including ancient hominins) are not respectful of (Dennell and Roebroeks 2005: 1101). Dennell and Roebroeks (2005) both clearly recognise the importance savannah grasslands have played in shaping the course of hominin evolution. The Savannahstan hypothesis suggests that in the Late Pliocene '*grasslands extended all the way from west Africa to north China*' (Dennell and Roebroeks 2005: 1102) implying that this would easily facilitate 'out of Africa' hominin migrations by early *Homo* and their antecedents as this would have allowed hominins to experience relatively homogenous conditions as long as they did not travel too far north (Dennell and Roebroeks 2005).

Dennell and Roebroeks suggest that Savannahstan should be imagined as a vast transcontinental zone of grassland throughout which our ancient ancestors roamed freely (Dennell 2004, Dennell and Roebroeks 2005, Kohn 2006). Hominin migration across southern Asia should be regarded as simply a latitudinal dispersion into the type of habitats (warm grasslands and open woodlands) to which they were already adapted (Dennell 2004, Dennell and Roebroeks 2005). Dennell and Roebroeks (2005) even suggest that at the time of the emergence of *Homo* Asia should be conceived of as having stronger adaptive selective forces than Africa, and thus potentially played a crucial role in the emergence of *Homo*. The stance taken in this study is that as the earliest evidence of *Homo* in Africa predates the earliest evidence of Homo in Asia by ~1Ma this part of the Savannahstan concept cannot currently be classed as having any validity (but the possibility exists that future finds may fundamentally alter this standpoint).

By removing the obstacles that certain less fire-prone environments (e.g. deserts) may have provided to migrating fire-benefitting hominins, the Savannahstan Hypothesis does provide a solution to the idea discussed in depth in this study that ancient hominins may have been benefitting from (and thus preferentially sought) repetitive and deliberate interactions with the Wildfire Package; and that this behaviour may not have had to be sacrificed as a cost of leaving Africa. The Savannahstan Hypothesis states that the African hominins living at Koobi Fora (1.9–1.7Ma) in Kenya, and their slightly later counterparts in Asia at 'Ubeidiya in Israel, and Majuangou in North China were all living in comparable linked grassland environments

(Dennell and Roebroeks 2005: 1102). Inhabitants of any of these locales would thus be expected to have the benefit of frequent Wildfire Package interaction opportunities.

As it would support and help to model the idea of fire being a strong selection pressure with potential and significant adaptive selective pay-offs (and therefore the broader concept that fire is very deeply rooted into the kind of behaviours basal to human culture and the *Homo* niche) it would be beneficial to the overall idea of very early hominin fire-use to wholeheartedly embrace the Savannahstan Hypothesis. However in this study the Savannahstan Hypothesis is not wholeheartedly embraced. This is because it is almost entirely based on plausibility rather than hard evidence (in the entire absence of hominin finds and confirmed archaeological sites in the period 3-2 Ma in Asia).

An evidential analysis can instead be used to argue against the idea that 'Savannahstan' accurately represents the macro scale Mid-Piacenzian and Pliocene-Pleistocene transition distributions of northern hemisphere continental sub-tropical ecosystems. Research by Geraards (e.g. Geraards 2006 and 2010) at Ahl al Oughlam in Morocco found that '*in spite of the clear similarities of Ahl al Oughlam with East African faunas, some significant elements of the latter are missing including Hominidae*' (Geraards 2010: 162); this lack of hominins at Ahl al Oughlam was very surprising, given the strong East African aspect of the fauna of this site; a fact that caused Geraards (2010: 166) to conclude that '*this can probably be taken as evidence of absence of hominids in North Africa at that time*'. Further casting doubt on the Savannahstan hypothesis is the acknowledgment that many grassland adapted genera present in Western Asia during the Late Pliocene appear to be absent from the North African record (Geraards 2010: 163). Geraards' (2010) results clearly show that in spite of the difference in latitude the similarities with excavated assemblages are greater with East African fauna rather than Eurasian fauna. As well as Pliocene faunal exchange patterns, Early Pleistocene faunal assemblages can also be used to support or refute the Savannahstan Hypothesis. The multi-level stratigraphic successions at the North African sites of Aı¨n Jourdel and Aı¨n Boucherit span the Late Pliocene through the Early Pleistocene and again do not show the kinds of faunal exchange (Geraards 2010) that would seem likely if the Savannahstan hypothesis was accurate.

Dennell (2004) appears to base significant portions of the palaeoclimatic reconstruction of Savannahstan on PRISM 2 reconstructions provided by Dowsett et al. (1999). Using PRISM2 data Dennell (2004: 209) suggested that '*grasslands ~3 Ma were probably continuous from West Africa right across to northern China*'; however even Dowsett now has major reservations about the methodologies employed in some of his previous work, and thus the quality of the conclusions drawn and models created from it (Dowsett et al. 2013). On a global level Dowsett et al. (2013:1) make the strong case that current methodologies used to reconstruct ancient marine palaeoclimates are very outdated and that '*a paradigm shift in marine palaeoclimate reconstruction is overdue*'.

Dowsett has been involved in the PRISM (Pliocene Research, Interpretation and Synoptic Mapping) project since it was launched in the early 1990s (e.g. Dowsett et al. 1994, Dowsett 2007, Dowsett et al. 2009), and has invested a significant part of its career in it. Previously PRISM (a compilation of marine proxy data) results have been reduced to single mean annual sea surface temperature values thus engendering an immense loss of palaeoenvironmental information (Dowsett et al. 2009); information required to create '*a true conceptual understanding of Pliocene climate*' (Dowsett et al. 2009:3) that in turn inform ancient habitat reconstructions on more local scales. Dowsett et al. (2009) argue that the next generation of marine palaeoclimate reconstructions are now capable of encapsulating all the available climate data, generated from an array of '*geological, biological and chemical proxies, with a focus on regional and process-driven climate change*' (Dowsett et al. 2009: 3). Dowsett et al. (2009) strongly suggest that this benchmark should become the new paradigm.

Improvements to PRISM will prove highly beneficial to researchers who are interested in topics such as the emergence of *Homo*, the earliest lithic technology and early fire theorists. This is because one of PRISMs (two) primary goals is to identify and characterise the nature and variability of climate during the Mid-Piacenzian (3.264–3.025 Ma) a period of great interest to paleoanthropologists due to the apparent hominid radiation that occurred during (as well as before and after) this period; it is a period that is also of particular interest to the FAF hypothesis (discussed in Chapter 4) because it directly precedes the earliest known appearance of *Homo*. The criticism of their own previous approaches (as discussed in Dowsett et al. 2013) shows the lack of credibility and robusticity leading researchers place on macro scale palaeoclimatic reconstructions dating to the 1980s, 1990s and 2000s; the same reconstructions relied upon by some paleoanthropologists (e.g. Dennell and Roebroeks 2005).

Additionally, the Savannahstan hypothesis seems seems unsatisfactorily, if catchily, named as Dennell and Roebroeks do not appear to adequately define the term savannah which has a multiplicity of different meanings to different people, suffers from colloquial misuse, and is not recognized within UNESCO classifications (Cerling et al. 2011). UNESCO classifications instead include terms such as 'grasslands' and 'wooded grasslands' which are quantified in terms of percentages (Ratnam et al. 2011). Cerling et al. (2011:51) make the point that '*an imprecise and often overly simplistic application of the definition of savannahs hinders progress in the debate over the timing and nature of their role in human evolution*'.

Here the Savannahstan Hypothesis is suggested to be a prime example of this phenomenon (Dominguez-Rodrigo 2014 provides a comprehensive review) as despite modern ecological definitions being comprehensive and often including structural, functional and evolutionary aspects (Cerling et al. 2011) Dennell and Roebroeks (2005) do not define their terms.

While the broad concepts of the Savannahstan Hypothesis have some appeal, it is abundantly clear that several significant structural weaknesses are identifiable. As well as the arguments laid out in this section Wil Roebroeks has significant prior history of postulating provocative ideas that are principally intended for testing (e.g. the 'short chronology' of Roebroeks and Van Kolfschoten 1994), and that have tended to generate the testing, but not withstand it. Similarly, the views regarding early fire espoused in Roebroeks and Villa (2011) are very much at odds with most lines of evidence focussed upon in this thesis, but have served the useful purpose of stimulating debate.

Omo-Turkana basin palaeoenvironmental data

Even if much macro-scale paleoenvironmental work can be deemed as of questionable value to early fire researchers looking for direct Wildfire Package evidence (due to a lack of temporal resolution - e.g. a horizon potentially covering many thousands of years); palaeoenvironmental proxies derived from material excavated from hominin bearing horizons at specific sites should still prove useful in terms of recognising dominant flora and fauna. From this data an assessment of the kinds of expected fire frequencies and fire intensities should be deducible from knowledge of landscape-specific modern fire regimes. Site specific studies with robust conclusions and fine-grained chronologies should be of significant interest to a thesis that attempts to reframe a topic of intense interest to paleoanthropologists and then introduce a hypothesis rooted in a mixture of evolutionary theory and plausibility (as this study will do in Chapter 4). Research at Lake Turkana provides a particular opportunity to consider site-specific palaeoenvironmental reconstructions in an effort to identify the presence of environments that might be highly fire prone, thus providing evidence of clear connections between Plio-Pleistocene ancient hominins and the Wildfire Package.

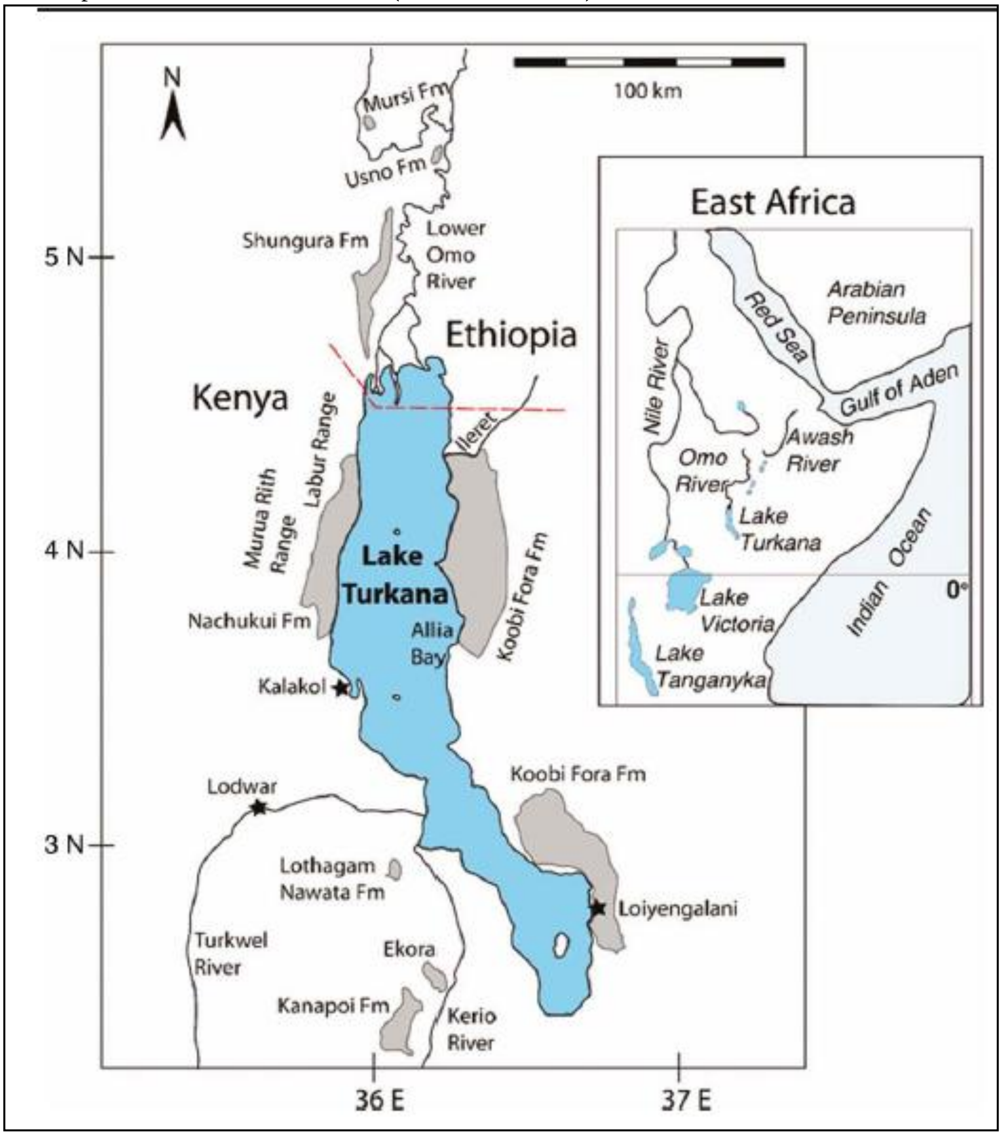
Before site-specific data from the Omo-Turkana basin is presented it should be clearly acknowledged that much published palaeoenvironmental work has been previously viewed as lacking precision due to preservational biases, time-averaging and the post-depositional transport of material (e.g. Dominguez-Rodrigo and Musiba 2010, Winder et al. 2013). Because of this it is very difficult to make direct connections between ancient hominin remains and specific (rather than general) ancient palaeoenvironments. Criticisms of palaeoclimatic reconstructions are now perhaps greatly accentuated due to a plethora of available new (often much more spatially and temporally precise) methodologies. Constantly improving and increasingly innovative methodologies can provide finer-grained resolution, or even entirely new proxies, for understanding correlations between climatic changes and trends in hominin evolution (e.g. the combination of radiocarbon, optically stimulated luminescence, U-series dating and paleomagnetic excursions used by Shanahan et al. 2013 to generate a fine-grained chronology from African lacustrine cores; and the close correlation between the presence of precession-driven, ephemeral East African deep-water lakes and some key events in hominin evolution identified by Maslin et al. 2014). These kinds of studies can now provide the backdrop for researchers to be able to significantly improve the confidence held in the reliability of palaeoenvironmental evidence, and thus also the results of reconstructive modelling.

The Omo-Turkana Basin includes the Lake Turkana Basin in northern Kenya as well as the lower Omo River Valley in southern Ethiopia (Plummer et al. 2015) (Fig 2.8). Parts of the Omo-Turkana Basin (e.g. the Shungura Formation) are well-dated (Bobe and Behrensmeyer 2004, Bibi et al. 2012) and provide one of the best studied geological and archaeological sequences in eastern Africa providing a framework for the study of East African hominin palaeoenvironments and paleoecology (Bobe 2011) and (with the application of the right methodologies and protocols) a glimpse of the environmental and faunal changes during a time when key events in human evolution were taking place (Bobe and Behrensmeyer 2004). Strata from the Omo-Turkana region span the period from ~7Ma ago to the present, and thus bracket the divergence of the LCA of humans and chimpanzees (Cerling et al. 2011). The region is renowned for its rich Pliocene and Pleistocene paleontological and archeological records (Plummer et al. 2015).

The Omo River has flowed from the Ethiopian highlands into the Turkana Basin for at least five million years (Levin et al. 2011). The presence of broad floodplains adjacent to the ancestral Omo River in combination with interfluves between alluvial systems produced a landscape conducive to soil development (Levin et al. 2011). Cerling (1986) estimated that annually the Omo River transported $10–20×10^{12}$g of sediment to the Turkana Basin. Periodic rapid addition of this new sediment to active floodplains regularly quenched soil development thus sealing the interval that each palaeosol records providing the substrate for the next pedogenic interval (Levin et al. 2011). This cyclic deposition created stacks of soils that provide researchers with snapshots (with a resolution of 10^3–10^5 years duration) of floodplain environments through time (Levin et al. 2011). Carbon isotope ratios ($\delta^{13}C/\delta^{12}C$) of pedogenic carbonates (pc) (as well as bulk organic matter and lipid biomarkers) can be used to determine the proportion of C_3 and C_4 plants growing in soils (Levin et al. 2011, Barboni

2014). δ^{13}Cpc records from Omo–Turkana are among the most complete temporal record of isotopic variation within paleosol carbonates from East Africa during the Pliocene and Pleistocene and they clearly highlight the fact that terrestrial environments in East Africa did not respond uniformly to climate change in the Pliocene and Pleistocene (Levin et al. 2011).

Figure 2.8: A map of the Omo-Turkana basin (from Feibel 2011)



The record in the Omo-Turkana basin begins with a period marked by relatively sparse woody cover in the Late Miocene to early Pliocene (Fig 2.9) (Cerling et al. 2011). These generally open habitats are directly associated with the earliest purported members of Hominini including *Ardipithecus sp.* (Cerling et al. 2011). Although perhaps best known for its fossil hominins (Bobe 2011) (a range of evidence from a number of different ancient hominin species spanning *Ardipithecus* to *Paranthropus* and *Homo* have been recovered [Cerling et al. 2011, Plummer et al. 2015]) it is also the source of one of the best African Late Cenozoic records of vertebrate evolution (Bobe 2011) which has been very helpful in aiding the reconstruction of ancient palaeoenvironments (Plummer et al. 2015) (see Feibel 2011 for a geological summary and Brown and McDougall 2011 for a chronostratigraphic summary). A variety of methods have been deployed within the Omo-Turkana basin to reconstruct its palaeoenvironmental history (e.g. sedimentological analysis of depositional environments, analysis of pollen and macrobotanical fossils, stable isotopic analyses of paleosol carbonates to reconstruct vegetation cover, analyses of changes in faunal diversity and the relative abundances of taxa over time) (Plummer et al. 2015:109 Passim).

Vegetation is a fundamental feature of a paleoenvironmental reconstruction because vegetation strongly determines the habitats of many species, primates included (Barboni 2014). The types of vegetation present on a landscape to a large degree fix the spatial and temporal availability of resources and greatly determine the type, presence, and abundance of predators and competitors (Brown and Kotler 2004, Barboni 2014); partly because the type and degree of vegetation significantly impacts on landscapes of fear (LOFs). In the Omo-Turkana basin preserved evidence of ancient vegetation includes silicified macro-remains such as pieces of wood as well as organic matter such as pollen grains (Barboni 2014 Passim). Bonnefille and Dechamps (1983) identified through a study of fossil plants that the palaeo-Omo-Turkana basin is characterised by a mosaic of grasslands, woodlands and forest including evergreen forests with epiphytes and drier deciduous forests with few epiphytes; subsequent studies have attempted to improve the resolution of these insights (e.g. Cerling et al. 2011, Levin 2011, Bibi et al. 2012 and Plummer et al. 2015).

Due to the fact that >50,000 specimens of fossil vertebrates were collected during the 1960s and early 1970s (Bobe et al. 2002) the Omo-Turkana basin data is viewed as providing a superb paleontological ‘mammal abundance’ database for identifying patterns of ancient environmental change and faunal turnover (Bobe and Eck 2001, Bobe et al. 2002); this is particularly true for larger mammals, especially Bovids (Bobe and Eck 2001). The habitat preferences of fauna found within hominin bearing archeological horizons can be used to infer ancient paleoenvironments and can therefore assist in reconstructing hominin habitat preferences by inference. Ecomorphological approaches that rely on the links between morphology and environment to identify patterns and trends were deployed by researchers such as Bobe and Eck (2001) (who concluded that faunal change in the Shungura Formation was a real phenomenon unlikely to have resulted from taphonomic processes) and Plummer et al. (2015) (who developed a brand of discriminant function ecomorphology models that linked astragalus [ankle bone] morphology to broadly defined habitat categories [open, light cover, heavy cover, forest, and wetlands] using principles of uniformitarianism applied to data collected from modern bovids of known ecology).

The study by Plummer et al. (2015) is focused on here as it represents a very recent study and showcases the most up-to-date methodologies. The methodology devised by Plummer et al. (2015) allows an abundance-based environmental reconstruction as opposed to many synecological methods that reconstruct palaeoenvironments through the presence or absence of particular taxa. Plummer at al. (2015) analysed 401 fossils from the Shungura Formation members B-G (3.4-1.9Ma) declaring an overall classification success rate of >82%. The analysis of Plummer et al. (2015) identified the full range of ecomorph categories (as was also found at Koobi Fora and Olduvai Gorge by Kappelman et al. 1997), thus demonstrating the existence of a wide range of habitats that existed in the Omo-Turkana basin; however 'heavy cover ecomorphs' (inferring woodland habitats) dominated the database which would, on a very simple level due to an associated less-frequent fire regime (relative to grasslands), appear to be counter to early fire theories. Vegetational environments were identified as being consistently heterogenous through time (Plummer et al. 2015). Even during periods that other palaeoenvironmental proxies had suggested were arid, woodland and forest ecomorphs persisted at significant frequencies (Plummer et al. 2015); thus highlighting the discord that different proxies (often generated from material excavated from the same horizon) can produce.

Plummer et al. (2015) also conducted a 'finer-grained analysis' that identified considerable variability in ecomorph frequencies over time; this highlights one weakness of palaeoenvironmental reconstructions which group samples by member as significant short-term variability can be masked. Additional inherent weaknesses exist with this approach; for example Plummer et al. (2015) themselves note that preservation biases frequently exists against small (< 15kg) mammal taxa, with their frequency within death assemblages often being lower than their frequency in living communities. Plummer et al. (2015) made a number of predictions based on the results of previous studies; not all of which were met. The part of their analysis regarding relationships between hominin evidence and bovid ecomorphology is of particular interest to this study.

Plummer et al. (2015:108) observed that the hominin genera *Australopithecus*, *Homo*, and *Paranthropus* were all identified within the Omo-Turkana basin (Fig. 2.9) and were all associated with a broad range of ecomorphs, indicating that all three genera were living in temporally variable and heterogeneous landscapes; however *Australopithecus* remains were predominantly associated with ecomorphs indicating a more woodland focus for this genus relative to *Homo*, and *Paranthropus*. Data from members E-G suggest that while *Paranthropus* and *Homo* had strong associations with different taxa (*Paranthropus* was strongly associated with species which preferred grassy settings, while *Homo* was more associated with bovids and *Papio Sp*. [identified by Codron et al. 2005 to prefer dry bushy habitats]); *Paranthropus* was also strongly associated with *Homo* thus indicating that subtle habitat preference differences existed between these genera (Plummer et al. 2015).

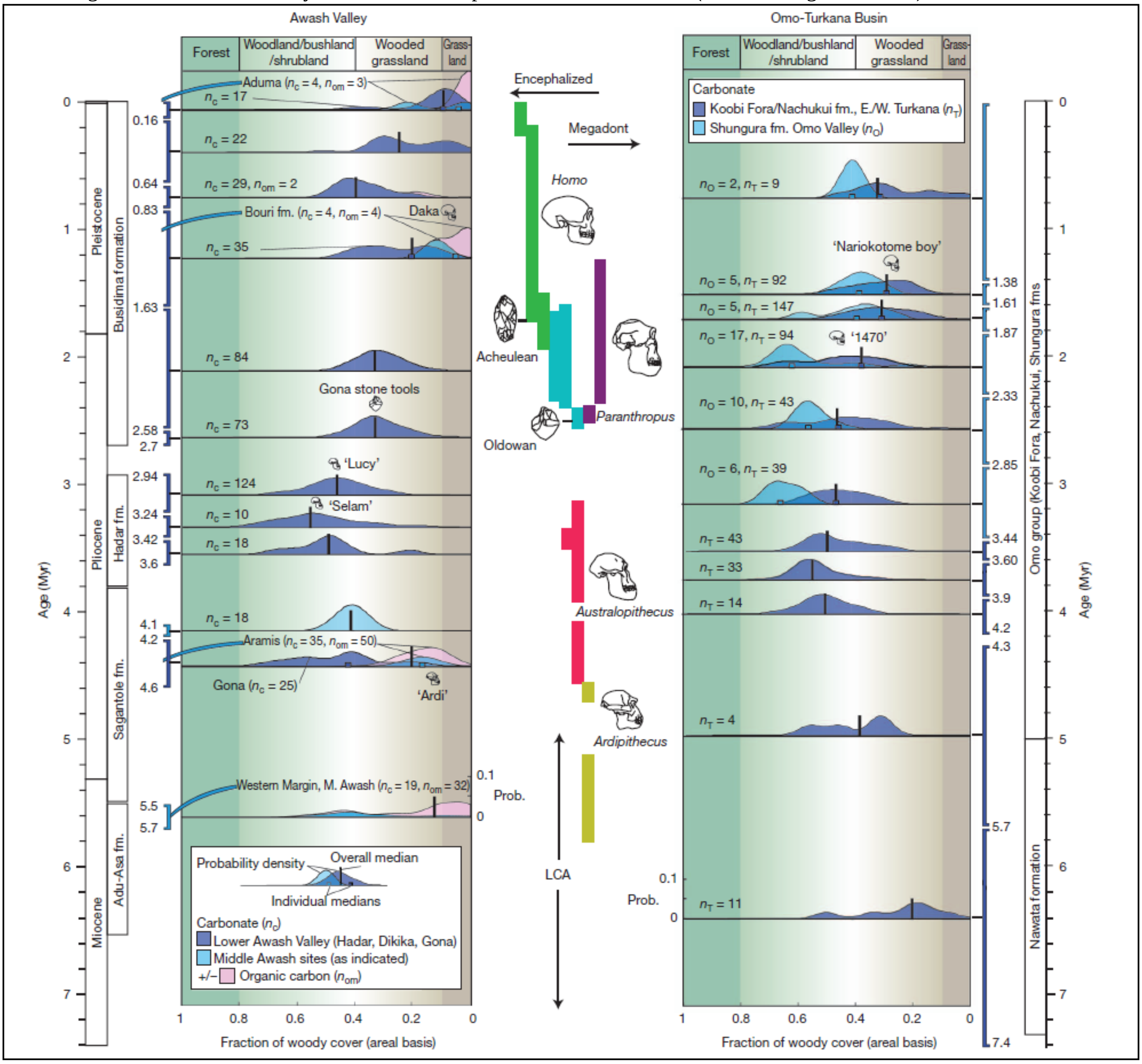
While analysis by Bobe and Behrensmayer (2004) concluded that *Paranthropus* containing deposits predate both the local appearance of *Homo* (by about 0.3Ma), as well as any significant increase in the prevalence of grassland environments, Bobe and Behrensmayer (2004) caution that it is not clear whether the earlier appearance of *Paranthropus* is attributable to an actual earlier origin or merely to the ability of researchers to recognize the specialized dentition of *Paranthropus* more easily than that of *Homo*. While this may not be immediately relevant to this study as the proposed deep root of fire may also incorporate Paranthropines (mostly ignored in this study as they appear to be evolutionary dead-ends), this confusion clearly shows that even high-quality heavily-sampled horizons do not provide clear incontrovertible evidence for researchers.

Moving away from the direct hominin evidence stable isotope evidence from Omo-Turkana basin horizons can also inform researchers. Cerling et al. (2011) used paleosol material from east African hominin bearing sites, including the Omo-Turkana basin, to reconstruct the fraction of woody cover over the last 7Ma. Cerling et al. (2011) identified and then used a relationship between the modern carbon isotope ratio ($\delta^{13}C/ \delta^{12}C$) in soils and the amount of woody cover in tropical environments and showed how this can be used as a calibration for estimating the degree of woody cover of palaeoenvironments (all based on the assumption that C_3 woody plants would have provided mammals with shade and shelter from the direct sun whereas C_4 grasses would not have done). It should be noted that this methodology does not distinguish between functionally distinct categories such as woodland, bushland and shrubland, which are defined (by UNESCO) by the height of woody vegetation rather than the degree of cover provided (Cerling et al. 2011). Knowing the degree of openness is also very useful for other reasons; Dominguez-Rodrigo (2001:77) found that, if Plio-Pleistocene carnivores were adapted like their modern counterparts, then the level of cover would significantly impact competition for resources between hominins and other members of the Plio-Pleistocene carnivore and scavenger guilds. Specific to the Omo-Turkana basin Cerling et al. (2011) found that $\delta^{13}C$/ $\delta^{12}C$ ratio data from 1,300 palaeosols dated to at least 6Ma show that woody cover was predominantly less than 40% at most sites (Fig. 2.9).

Bibi et al. (2012) deduced that a $\delta^{13}C$ increase in their data over time was not correlated with a visible expansion of grassland habitats (and thus loss of tree cover), or indeed with proportional increases in the proportion of grazing mammals. Furthermore, Bibi et al. (2012) stress caution regarding conclusions drawn from plaeobotanical stable isotope analysis stating that inferences about the relative proportions of grasslands/woodlands may be confounded by the realisation that C_3 grasses may have made up a larger proportion of lowland African plant biomass during the Pliocene than they do today (as per Rossouw and Scott 2011). In the Omo-Turkana data it is therefore possible that a $\delta^{13}C$ increase may not represent a significant replacement of trees by grasses, as a replacement of pre-existing C_3 grasses by C_4 grasses is also plausible (Bibi et al. 2012). Perhaps pollen data can help to further elucidate researchers?

Another method of reconstructing palaeoenvironments is through the analysis of fossil pollen that provides information about the relative abundance of arboreal (versus non-arboreal)

Figure 2.9: A composite record of palaeosol stable isotopic composition from the Awash Valley, Ethiopia (left) and Omo-Turkana Basin, Kenya and Ethiopia (right). A hominin phylogram is shown at the centre (adapted from Wood and Lonergan 2008). Stable isotope data are presented as normalized probability density functions of predicted woody cover determined for palaeosols in a series of temporal bins defined for each basin. The median value of woody cover for all data from each temporal bin is shown with a narrow white bar. Shungura formation data are shown with probability density functions distinct from the remainder of the record (Koobi Fora and Nachukui formations, East and West Turkana). The number of analyses from the Omo Valley (nO) and the Lower Turkana Basin (nT) are indicated. Hominin species ranges are spread according to their age distribution (vertical axis) and roughly corresponding to their anatomical features (horizontal axis). Major archaeological innovations of early stone tool development are also indicated (from Cerling et al. 2011).



vegetation (Bonnefille 1994, Bobe and Eck 2001). High percentages of arboreal pollen are indicative of relatively closed woodlands, while high percentages of grass pollen are indicative of more open environments (Bobe et al. 2001). However this methodology is riddled with issues: i) plant species may have differing production and distribution strategies that can result in in-sample relative abundances of various pollen taxa not necessarily being proportional to the representation of taxa in the original plant community (Bonnefille 1995); ii) the nature of a depositional environment can also play a role in determining the composition of pollen assemblages (Bonnefille 1995); and iii) pollen samples can be heavily biased toward wind-pollinated species and therefore are likely to represent taxa from a wider range of habitats than the horizon being sample may have encompassed (Bonnefille 1995).

The Omo-Turkana basin provides an excellent example of this last point; excavated pollen assemblages regularly contain montane forest taxa, whereas montane species have been found to be conspicuously absent from samples of fossil wood (Bonnefille and Dechamps 1983). These issues mean that while pollen grains can provide basic insights into floristic aspects of Plio-Pleistocene vegetation, plant fossils cannot be used to reconstruct the 'living distribution of taxa on a fine [spatial] scale' (as per Andrews and Bamford 2008). It has been suggested during this study that site-specific pollen studies may greatly enhance the case for early fire theorists by closely tying together ancient hominins with landscapes with high frequency fire regimes (e.g. 'Zambezian like' flora – see section on *hypothesised ancestral fire relationships* [Ch.4]); the response here is that this idea is too riddled with the issues laid out here (and in more detail in Bonnefille 1995) for this correlation to stand up to detailed academic scrutiny. In addition to this pollen grains are rarely found preserved at hominin sites (Barboni 2014 Passim); for example at Laetoli less than 10% of samples provided exploitable pollen assemblages (> one hundred samples were analysed) (Barboni 2014).
It is clear from the amount of published material that excavated Omo-Turkana basin deposits have undergone significant amounts of analysis from a broad range of methodologies. While

it is undeniable that each of the different levels of resolution provided by the Omo-Turkana basin palaeoenvironmental record contributes unique and important information that combined offer a multi-layered record (Bobe and Eck 2001, Bobe et al. 2002, Levin 2011, Bibi et al. 2012) from the perspective of early fire researchers there is not too much firm evidence to grasp hold of. This may partly be because different ecological proxies in actuality sample a broad range of different spatial and temporal scales (Bibi et al. 2012); none of which are, in this study, classed as of sufficiently high resolution to be of great value to early fire researchers.

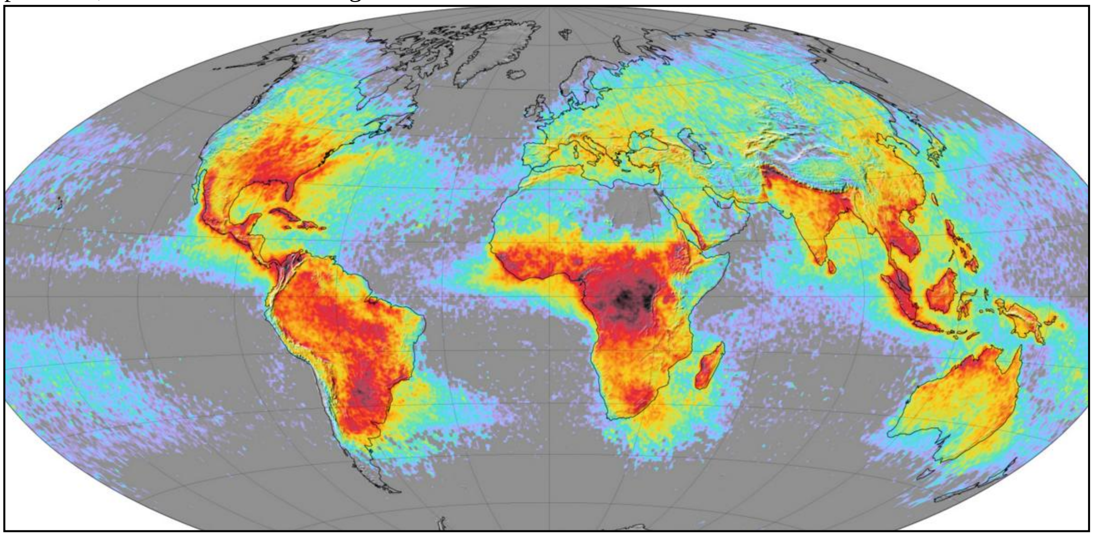
The timing of certain environmental shifts in the Omo remain in doubt as the evidence of paleosols, paleobotanical remains, and micromammals is not continuous enough to elucidate the exact timing and rate of any visible changes (Bobe and Eck 2001). For example, according to Bibi et al. (2012:3) the raw data suggest that vegetation, faunal and evolutionary responses between 3 and 2.5 Ma in the lower Omo Valley may have been decoupled on the order of 0.1Ma or more (Bibi et al. 2012). Bibi et al. (2012:4) stress that their data differs significantly from that of Levin (2011) and Cerling (2011) despite analysed material coming from nearby formations within the Omo-Turkana basin. Bobe et al. (2002:494) drew the conclusion that the paleo-Omo River '*helped to buffer the floodplain plant and animal communities from the effects of larger-scale climate cyclicity, at least up to 2.5 Ma*' thus clearly showing the impact that local topography and geographical features can have on palaeoenvironmental data. Cerling et al. (2011:55) concur with the conclusion of Bobe et al. (2002) again stressing that areas close to river systems would have supported more dense woody cover as they would be nourished by more abundant ground and surface water sources. This supports the idea that many ecologically autonomous regions (producing a multiplicity of different niches) were available to hominins at this time, which only high resolution local research can ascertain; it is argued here that with respect to early fire this resolution has yet to be reached.

Bibi et al. (2012) deduced that multiple disparate Pliocene herbivore lineages exhibiting similar and contemporaneous changes in dietary behaviour suggest a common environmental driver. The results of Bibi et al. (2012) do raise significant questions about the resolution at which different ecological proxies may be comparable, the correlation of vegetation and faunal change, and the interpretation of low $\delta^{13}C$ values in the African Pliocene. In this study the position is taken that site specific studies should only be seen as a credible foundation for models attempting to recreate ancient hominin behaviour once much more fine-grained and high-resolution methodologies have been applied to generate data. Increasingly nuanced future methodologies will be hopefully much less prevalent to the issues identified here and also by Winder et al. (2013) who stressed the problems of preservational biases, time-averaging and the post-depositional transport of material.

Palaeolightning distributions

To generate an idea of the kinds of environment features that would result in potential high frequency Wildfire Package interactions it is not just the floral nature of the landscape that is of interest. Along with vegetative palaeodistributions an understanding of lightning distributions (the most common source of natural ignition), and the forces driving patterns of lightning distribution (e.g. topography and dominant monsoon cycles) will greatly aid the quality of ancient hominin niche modelling. An analysis of NASA annual global lightning strike data (lightning.nsstc.nasa.gov or earthobservatory.nasa.gov and Fig. 2.10) shows that global heterogenic patterns of lightning strikes are strongly biased towards humid thickly vegetated equatorial regions. Further analysis of NASA online monthly data shows that this

Figure 2.10: An annual (NASA) Global Lightning strike map. Data is presented in units of lightning strikes/ per km^2/ per Year; darker colours denote greater densities[10].



pattern is roughly consistent throughout the year. If principles of uniformitarianism are evoked then a modelling of ancient African wildfire regimes with a focus on patterns of potential ignition, rather than fuel availability, is seen to be worthwhile.

Currently mountainous equatorial regions of African experience the globally highest density of lightning strikes (Fig. 2.10). If the impact of modern humans is discounted then the presumption could be made that lightning strike density may be linked more with closed canopy landscapes rather than pure grassland environments. The Omo-Turkana basin and Olduvai Gorge are within some of the highest density regions; the region with currently the highest density of annual lightning strikes encompasses an area including the Rwenzori Mountains on the Uganda/Congo Border and the Virunga chain in Uganda and Congo.

Based on analysis of lightning distribution data it would not be difficult to make connections between the Wildfire Package and the kinds of mosaic woodland (and associated more closed canopy woodland environments) that current broad low-resolution palaeoenvironmental analysis suggests was part of the mosaic environments seemingly habitated by Late Pliocene

[10] Accessed 20th November 2017 - earthobservatory.nasa.gov/IOTD/view.php?id=6679

ancient hominins (e.g. Plummer et al. 2015). While lightning may be most frequent in the tropics it rarely causes fires in the rainforest habitats of modern apes. Savannah zones however have high frequencies of both lightning and fires, especially in the first storms that presage the end of the dry season (Sankaran et al. 2005; Beringer et al. 2007).The idea that topography and latitude may play just as much a role in determining a wildfire regime than vegetation can, to some extent, remove the need for early fire theorists to show the presence of appropriate fire-connected flora and instead look at supporting early fire hypotheses with alternative connections between the prevalence of wildfire and other landscape features.

It is not known whether ancient fire regimes were more driven by lightning strikes than the type or abundance of available fuel (however wildfire characteristics such as fire intensity and spread rate are definitely heavily impacted by fuel type and/or abundance). An analysis of publicly available NASA data (e.g. Fig. 2.10) shows that most highly significant ancient hominin localities just happen to also currently be global lightning hotspots. If a similar distribution pattern existed in the Late Pliocene and Early Pleistocene then these same areas can be modelled as having had potentially very high frequencies of wildfire. East Africa is a global lightning hotspot, and so is the area containing the majority of South Africa's ancient hominin sites (e.g. the Cradle of Mankind area near to Johannesburg) (Fig. 2.10). Areas of Pakistan, China and Java are other global lightning hotspots that also happen to be areas where some of the oldest well-dated non-African ancient hominin sites are located.[11] This simple analysis is suggested here to be able to significantly help early fire theorists who hope to highlight the strength of the potential adaptive selective pay-offs obtainable through a close association with the Wildfire Package and its potential affordances.

[11] It is also acknowledged that Dmanisi in Georgia is not currently a global lightning hotspot. Detailed modelling using ancient climatic, geological (focussing on tectonics) and oceanic current patterns is needed to identify if the situation was any different in the Early Pleistocene when some of the earliest known non-African hominins resided in this area.

In this study the stance taken is that general long-term global climatic trends can inform researchers that construct basic models which do not necessarily require being tied to specific sites or ancient hominin species; instead an understanding that long term trends and behaviours may run as behavioural themes across a multiplicity of ancient hominin species (whose relative taxonomy remains unclear) is preferred. An example of this approach is to acknowledge that a late Pliocene long-term trend of global cooling and drying may have resulted in areas with significantly reduced primary production and also perhaps local scarcity of certain resources. Engagement at this level of chronological resolution enables researchers to broadly model hominin responses to evolving palaeoniches (including potential alterations to size, morphology, diet and behaviour and thus landscape-use and choice) without having to provide (or rely on) site-specific proof which with currently may not yet be detectable with sufficient precision.

At coarse levels of spatial and temporal resolution innovative ways of shaping or building ancient niches can be considered that perhaps are not yet readily evident in the fossil or archaeological record. This perspective strongly accords with the idea that *Homo* antecedents may have required access to ecologically autonomous regions to survive. In this study the prevalence of Wildfire Package interactions (and thus the presence of fuel and natural ignition sources), and its multiple potential affordances and adaptive selective pay-offs, is regarded as an important way that ancient hominins were able to successfully exploit their niches and can thus be viewed as an important factor in, at times, guiding significant aspects of hominin evolution. Specific scenarios and theories have been suggested that highlight the involvement of Wildfire Package affordances. A few of the more important and well-known ideas and scenarios are now presented in detail.

Chapter 3 – Origins of hominin fire-use – current ideas

In this chapter published early fire scenarios (e.g. the Cooking Hypothesis and the Pyrophilic Primate Hypothesis) are assessed against three criteria identified in this study as a way of testing the potential viability of any early fire theory or evolutionary driving force. As well as previously published material, a new scenario the Optimal Fire Foraging scenario' is presented here which was created (and aspects of it were then tested) during the early formative part of this Ph.D study. This new scenario is proposed based on foraging benefits inherent within affordances created by Wildfire Package impacts on landscapes.

The stabilisation of hominin Mode 1 fire would not have arisen simply by chance. Specific distinct selective advantage(s) must have existed to attract ancient hominins to interact with aspects of the Wildfire Package. Due to the inherent dangers and risks of wildfire (e.g. smoke, heat and flames) to transition from 'Non-Fire-users' to users of Mode 1 technologies or strategies requires the invoking of respected adaptive selective forces. While evolutionary theory is broadly based on the premises of 'natural selection' and 'survival of the fittest', it is highly nuanced. It is widely accepted that in most cases evolution proceeds by mutations arising by chance, with those that impart an adaptive advantage more likely to be retained by natural selection (Madrell 1998, Campbell and Reece 2005)[12]. However here it is proposed that when looking at the evolution of foraging behaviour in cognitively complex animals that are very much aware of their landscapes behavioural mutations may not only arise through chance; factors such as the specific circumstances of an individual or group may impact on their boldness, curiosity or need. Rather than being simply random mutations, it is proposed here that behavioural changes may derive from cognitive connections made based on information received and processed (or learned behaviour) which then underpin subsequent

[12] Greater understanding of epigenetic changes may challenge this model

random mutations; mutations that would then still need to be retained by natural selection. Due to the very real dangers of associating with fire, were no biological fitness benefits to ensue from initial interactions then it appears exceedingly difficult to justify a case for that trait spreading and stabilising.

Fire is in essence the release of potential energy that then impacts surrounding environs but it also changes the distribution and nature of certain resources enabling many different affordances. Modern humans have harnessed this potential energy (to help with keeping warm, manufacture of materials and movement) and have utilised changes to the distribution and nature of certain resources (including the behaviour of other parts of the ecosystem) to their advantage. With the exception of the 'Social Brain Hypothesis' all other ideas postulated and published to try to explain how and why (as yet unidentified) hominins started to interact with fire are connected to savings or changes within energy budgets explaining the initial attraction to the Wildfire Package. This may be because for an adaptation to stabilise quantifiable benefits must accrue. Economic theories are popular as economic benefits are testable, easily calculable by researchers, fit with established evolutionary theory and thus are easy to model. Other benefits are however accruable, that are not immediately easily mathematically quantified, but that can generate significant adaptive selective pay-offs.

Fire has undoubtedly been important in different ways for different societies at different times; and still is important in modern times despite, particularly in urban societies, often being hidden away (Pyne 2016). This acknowledgment highlights the fact that the adaptive selective forces driving the initialisation and stabilisation of hominin fire relationships, and the nature of the initial fire-use strategies, may be very different to modern uses and/or those inferred from the archaeological record. The possibility exists that anthropogenic fire is exaptive (i.e. a shift in the function of a trait during its evolutionary history – common in both mammalian anatomy and behaviour). How then can researchers hope to identify the initial reasons for hominins and fire to interact? The only realistic way appears to be through theoreticising; a major focus of this study. Hypotheses and theories can only ever be as good as the data and assumptions used as foundations; the clearer and broader the foundations then the more stable and robust the model or theory should be.

Certain fire-use strategies require hominin fire-use to be seen as exaptive (e.g. using fire as a social focus) otherwise they can be dismissed as teleological or teleonomical. Once greater familiarity and knowledge of fire had been attained, including the effects of fire on the landscape and other parts of the ecosystem, hominins could then adapt their fire-use strategies towards the now visible benefits. In this study the view is taken that the initial attractant to the Wildfire Package is highly likely to be exaptive. This would require the initial exploitation of Wildfire Package affordances to be different to subsequent major uses of fire (whose benefits would not be realisable until many interactions with fire had already taken place and a relationship with fire already instigated). In a similar way to dinosaurs having evolved feathers for warmth or display purposes (e.g. courtship and fighting) and then adapting them to flight, currently unknown ancient hominins may have taken up fire-use due to one (or a combination of many) adaptive selective forces. New models allow different aspects of this early relationship to be clearly visualised dissected and debated, thus allowing paradigms and prevalent ways of thinking to evolve and transform.

Models of the earliest hominin fire interactions must include key ‘real world’ processes (like all good models it will be in a simplified form [Gentleman 2002]), so that trends relationships and patterns can be identified. Researchers can never know with 100% confidence what the nature of the very earliest hominin fire interactions was but a number of very simple ways to benefit from the Wildfire Package can be envisaged (see Table 2.2).

Criteria for accepting or rejecting the viability of an early fire theory

For any hypothesised adaptive selective driving force to be accepted by researchers a number of conditions have to be met. In this study three criteria are proposed that have to be met for any theory of the initial uptake of hominin fire relationships to be viewed as plausible and credible. These are:

i) Any theorised biological driver needs to fit with respected evolutionary theory and create an adaptive pay-off.

For a model or hypothesis to stand up to scrutiny firm theoretical foundations are required. A hypothesis not grounded within tenets and precepts of established evolutionary theory will not gain credence within the research community. If no selective advantage (adaptive pay-off) is attained or fitness benefit accrued then a hypothesis would be viewed as failing to meet this condition.

ii) Any theorised biological driver needs to be viewed as plausible from the perspective of a non-fire-using hominin.

The end result cannot be the driver - the purpose cannot be an explanation for natural phenomena (Reese 1994). This would be teleonomy/teleology which is contrary to accepted logic. To accurately model the very earliest hominin fire interactions and attractants researchers need to attempt to view interactions from the ground-level perspective of ancient hominins (if this is possible) rather than viewing the end result and reconstructing the path back. The transition to fire-use cannot be predicated on a 'purposeful' argument: for example hominins wanted to cook food so they started using fire; or hominins needed greater protection so they started using fire. Therefore researchers cannot cite the desire for things like warmth or cooked food (both seemingly teleological explanations) as the motivation for the instigation of hominin fire relationships.

iii) Any theorised biological driver must not directly result in obligate fire-use.

The uptake of fire-use was undoubtedly a long slow series of developments (this statement is partly based on the speed of Plio-Pleistocene lithic technological development, and also the fact that no other researcher has clearly posited and modelled a speedy uptake and development of fire). No researcher has suggested that hominin fire-use started with hominins with mode 3 technologies and knowledge, which current evidence strongly suggests was within the last million years (this figure is probably closer to 500,000Ky but a more conservative figure of 1Ma would also account for a favourable interpretation of the evidence from sites such Wonderwerk Cave [e.g. Beaumont 2011]). Being dependent on fire requires, as a minimum, constant access to fire; which is achievable with Mode 2 technologies and social structures (Twomey 2011) but is much more plausible with Mode 3.

As highlighted by Twomey (2011: 93): "*The problem with naturally occurring fires as a potential source of ignition is that they are infrequent, ephemeral, unpredictable, dangerous and stochastically distributed in any given bioregion*." Thus naturally occurring fires would not have been sufficiently feasible for most, if any, obligate fire-users to depend on. This would be especially true for Palaearctic hominins as the fire frequency for naturally occurring fires in some ecotypes (e.g. high latitude arboreal forests) can be measured in years, decades or even centuries (Bergeron et al. 2014). The exception to this may have been the inhabitants of certain strongly monsoonal environments that have distinct dry seasons which terminate with natural ignition events in the form of lightning strikes striking dry landscapes.

The very earliest interactions with the Wildfire Package must be viewed as having been undertaken by hominins taking advantage of naturally ignited conflagrations or the effects on the landscape of naturally ignited conflagrations. Some benefit must have been realised from this behaviour thus stimulating repetitive interactions and eventually a broad suite of fire based adaptations and strategies. Twomey identified a number of key cognitive functions that obligate fire-use requires including anticipatory planning and delayed gratification (Twomey 2011), while Ofek (2001) highlighted the need for special arrangements for division of labour and strategies to reduce free-loading. If societal and cognitive pre-conditions (as suggested by Twomey 2011 and Ofek 2001) were required for obligate fire-use to appear and coalesce then it further reinforces the argument for a deep fire root; any theory or model that leads straight to obligacy will not allow sufficient time for these adaptations to occur and become fixed.

Existing ideas of how fire-use became imbedded into hominin culture and lifeways are now assessed against these three prescribed criteria.

Expensive Tissue Hypothesis

The Expensive Tissue Hypothesis is based on the premise that only so much energy is available to an organism to build and maintain itself (Aiello and Wheeler 1995). Brains are metabolically highly costly (Aiello 1997) and according to the Expensive Tissue Hypothesis for hominin encephalisation to occur savings had to be made by reducing the cost of other metabolically expensive organs (e.g. the gastrointestinal tract) (Aiello and Wheeler 1995). The Expensive Tissue Hypothesis argues that the gastrointestinal tract is the only 'expensive' organ in apes that correlates negatively with brain size (Aiello and Wheeler 1995, Potts 2011); linkages are clearly visible between changes in hominin diets, the relative size of their gastro-intestinal tracts and their cranial volume (Aiello and Wheeler 1995). Aiello and Wheeler (1995) do not specifically implicate fire as the process enabling *Homo's* encephalisation, but the Expensive Tissue Hypothesis is a fundamental idea that underpins the Cooking hypothesis of Wrangham and colleagues. The Expensive Tissue Hypothesis suggests that a significant increase in hominin dietary quality allows for a reduction in the quantity of gut required making energy available for the production of brain material; utilisation of Wildfire Package affordances is one potential way dietary quality increased (but not the only way – for example the advent of 'big-game hunting' has also been proposed). Recently 'a fat-brain trade-off underlying the Expensive-Tissue Hypothesis of brain enlargement' has been proposed as an alternative to the gut-brain trade-off (Potts 2011).

The theoretical foundations of the Expensive Tissue Hypothesis have been repeatedly challenged. The Expensive Tissue Hypothesis as a concept was contested by Navarrete et al. (2011) who conducted an across species study using 100 taxa including 23 primate species and identified that while in most mammals brain size correlates negatively with the amount of body fat, it does not correlate negatively with gut size (Navarette et al. 2011). If the expensive tissue hypothesis does not hold for other species studied it may however still be valid for *Homo*; it could be a unique behavioural autapomorphy that characterises *Homo* (Potts 2011). While in the strictest sense not an 'early fire' theory, the Expensive Tissue

Hypothesis is included here as it partly underpins the 'Cooking Hypothesis'; and also to some extent both the 'Pyrophilic Primate Hypothesis' and the 'Optimal Fire Foraging scenario'. Within these three hypotheses the idea exists (to some degree or other) that dietary quality improvements created by exploitation of different Wildfire Package affordances was a mechanism by which the Expensive Tissue Hypothesis was able to manifest.

As it is not an early fire theory in the strictest sense the Expensive Tissue Hypothesis is not tried against the three criteria laid out previously. While it is theoretically plausible that processes described within the Expensive Tissue Hypothesis were involved in the complex process of fire-mediated changes to hominin morphology and lifeways, the Expensive Tissue Hypothesis cannot be viewed as the driver for anthropogenic fire relationships. The desire to encephalise could not have been a reason for hominins to adapt behaviour; encephalisation was a result of changes to energy budgets, social structures (e.g. increased cooperation [Anton et al. 2014]) and/or the need to master new strategies, environments and technologies which probably entailed a complex network of feedback mechanisms.

The Cooking Hypothesis

According to the Cooking Hypothesis (e.g. Wrangham et al. 1999, Wrangham 2009), through cooking (the chemical alteration of a resource through interaction with fire [Parker et al. 2016]) Early Pleistocene *Homo* managed to evolve an archaeologically visibly more efficient digestion system with reduced digestive effort identified by smaller teeth and shorter intestines (Wrangham et al. 1999), and, ultimately increased caloric resources to support subsequent encephalisation. Wrangham (2009) argues that cooked food also drove social developments including pair bonding and a gender division of labour. Underlying the

Cooking Hypothesis is the idea that savanah inhabiting hominins would struggle at certain resource stressed times of the year to obtain sufficient resources to balance energy and nutrient requirements (Gowlett 2016). Alternative food sources would be required particularly during dry seasons (Laden and Wrangham 2005).

Relative to a raw food diet cooked food has many advantages including: cooking can substantially increase an organisms energy intake (Wrangham 2009); digestive processes' start prior to consumption as cooking gelatinises starch (Wrangham 2009); cooking decreases the toughness of food reducing the need for high bite forces and potentially significantly changing feeding patterns (Organ et al. 2011).; cooking reduces chewing time and effort (Boback et al. 2007); cooking, roasting, or smoking can be a means of detoxifying certain poisonous foodstuffs (Wrangham 2009), thus substantially broadening the range of edible species for hominins (Alperson-Afil and Goren-Inbar 2010); and, cooking reduces pathogens (Zink et al. 2015). In support of the Cooking Hypothesis, using genomic analysis Wang et al. (2004) identified bitter taste receptors cells that were selected against during the Early Pleistocene. Wang et al. (2004) posits this as evidence of cooking; by consuming sufficient amounts of cooked food hominins reduced their exposure to toxins as a result negating selective pressures for bitter taste genes.

Wrangham (2009) argues that species respond to dietary change by exhibiting rapid and obvious anatomical adaptations, and that species adapt to their diet; the 'tight fit' between food and anatomy is driven by food and not anatomy. By utilising information within the fossil record clear inferences as to when hominins started eating cooked food (which by necessity requires some degree of consistent fire usage) can be recognised (Wrangham 2009). Wrangham et al. (1999) makes a number of correlations between the Cooking Hypothesis and aspects of the social structure and behaviour of Early Pleistocene hominins including reduced sexual dimorphism and cognitive capacity (e.g. forward planning and trust which enable delayed consumption of food). The Cooking Hypothesis as presented by Wrangham and colleagues is initially quite compelling, and it is possible to find support within the literature (e.g. Berna et al. 2012), but the Cooking Hypothesis is by no means the only explanation that explains increased gracility and improved dietary quality in Early Pleistocene *Homo*. Any theory that can explain a significant increase in dietary quality (e.g. increased consumption of meat acquired through power scavenging [O'Connell et al. 2002]), or even a simple overall increase in energy intake acquired solely through the process of a dietary changes (Allen and Kay 2012) would allow energy budgets to increase without requiring the cooking of foods.

Gowlett makes the case that "*In a sense, the Cooking Hypothesis is proved, in that all modern humans need cooked food*" (Gowlett 2016: 3) but in this study this viewpoint is not wholeheartedly agreed with; obligate consumption of cooked foods may have arisen much later than the Cooking Hypothesis suggests, and may be linked to much later encephalisation trends than those proposed by Wrangham and colleagues. While the Cooking Hypothesis does fulfil the requirement of fitting with respected evolutionary theory and providing a significant adaptive selective pay-off, and a case is probably constructible to argue that it can be viewed as plausible from the perspective of a non-fire-using hominin (e.g. that hominin foraging within wildfire burnt environments for burnt fire mortalities would lead to a taste for cooked food, and then a desire to replicate this phenomenon), the Cooking Hypothesis however fails the third test (fire obligacy).

By following Wrangham and colleagues theories it results in obligate fire-use prior to 'out-of Africa' migrations and well before the known advent of Mode 3 technologies and knowledge.

Wrangham himself labels the mismatch between the archaeological appearance of Mode 3 and his association of certain morphological traits of Early Pleistocene hominin fossils with the consumption of cooked foods as the 'cooking enigma' (Wrangham 2009). Wrangham also appears to favour aspects of 'accidental discovery' within his theories (Parker et al. 2016), suggesting that at times knapping might have created small fires which were utilised and played with by curious and inquisitive juveniles or young adults (Wrangham 2009). Twomey (2011) pointed out how unlikely this would be as for sparks to occur pyrite has to be used (Stapert and Johansen 1999) and worked pyrite from the Lower Palaeolithic has yet to be conclusively identified at any site (Stapert and Johansen 1999) let alone a site with other evidence or suggestions of hominin fire interactions. Accidental discovery of fire cannot be entirely ruled out, but any hypothesis' that relies on serendipity inevitably results in a weakened hypothesis.

The Social Brain Hypothesis

The 'Social Brain Hypothesis' as a whole is centred on the notion that increasingly complex social lives and social structures drove encephalisation (Gamble et al. 2011). The Social Brain Hypothesis has at its foundation the realisation that a strong correlation exists between the size of primate communities and neocortex size and that for encephalisation to occur significant social changes must be mobilised (Dunbar 1998, Gamble et al. 2011). Within the Social Brain Hypothesis novel cultural and biological adaptations are viewed as evolutionary responses to increased cognitive load. The Social Brain Hypothesis views the onset of anthropogenic fire as a necessary cog linking in with other early Pleistocene hominin developments such as the development of Acheulian lithic technology. The Social Brain

Hypothesis views the onset of anthropogenic fire as perhaps having been synchronous with the development of complex social networks and language (Dunbar et al. 2010).

Fire-use is suggested to have significantly re-ordered chronological scheduling and time use by altering circadian rhythms (Dunbar et al. 2010). An increase in social space by a hypothesised four hours in the evenings (Gowlett 2010) is envisaged as allowing the integration into groups of more individuals and sub-units thus creating larger communities whose members require large brains to manage significant increases to cognitive load (Gamble et al. 2011). Unique among extant primates, peak alertness in *Homo sapiens* is in the early evening when other primates are bedding down (Gowlett 2010); thus under the Social Brain Hypothesis fire is a means of extending the length of the day and would have led to a genetic underpinning (Gowlett 2010). Within the Social Brain Hypothesis fire is viewed as potentially having driven the development of the concept of 'home', thus providing a structure for cultural interactions (Gowlett 2010). Through a Social Brain Hypothesis 'lens' Early Pleistocene hominin fire-use should be viewed as an important facilitator in a triad of: i) detailed environmental knowledge, ii) social collaboration and, iii) diet change (Gowlett 2010).

When applied to the three criteria developed in this study the Social Brain Hypothesis passes the first test in that no part of it is contrary to accepted evolutionary theory; however it struggles to sail through the other two criteria intact. While the placing of the start of anthropogenic fire-use within the triad of detailed environmental knowledge, social collaboration and diet change seems entirely appropriate it cannot be said that Early Pleistocene hominin foragers deliberately interacted with fire as a means of extending available social time. While this acknowledgement does not in any way detract from the value of the Social Brain Hypothesis as a wider theory, under the Social Brain Hypothesis anthropogenic fire-use must be viewed as an exaptation; i.e. the Social Brain Hypothesis cannot adequately explain the initialisation of hominin fire relationships, although it can adequately explain how interactions with fire helped to form the hominin social brain.

Perhaps more problematic is the question that once circadian rhythms have been altered is obligate fire-use required? If so, in a similar way to the Cooking Hypothesis, the Social Brain Hypothesis (archaeologically observed through encephalisation trends) is not synchronous with available evidence for ignition at will. The Social Brain Hypothesis appears also to rely on a prior shift to a higher quality diet. This shift could perhaps have been fuelled by fire-mediated relationships with the Wildfire Package discussed in the Optimal Fire Forager's Hypothesis and the Pyrophilic Primate Hypothesis. The conclusion reached in this study is that the Social Brain Hypothesis is a coherent, highly plausible, well constructed model with many merits (that I consider myself a proponent of) but it does not and cannot explain the initial interaction of hominins and fire. Under the Social Brain Hypothesis fire must be seen as exaptive and a different adaptive selective force or driver must be sought to explain the nature of the initial relationship. However the Fear and Flames (FAF) hypothesis (Chapter 4) outlines a new pathway into hominin fire-use that also effectively acts as part of the Social Brain Hypothesis' *deep root*.

Optimal Fire Foragers scenario

This study, begun under the working title '*Landscape level investigations into the onset of the initial hominin fire interactions*', was initially focussed on the idea that foraging within wildfire burnt environments offered fitness benefits to ancient hominin foragers and that perhaps therein lies the answer to the '*Why did hominins first start interacting with fire*?' debate. The initial central research focus was that fitness benefits (or adaptive selective pay-offs) would accrue to foragers in the form of easily improved dietary quality relative to foraging in similar but un-burnt environments. This idea provides the central focus to the Optimal Fire Foragers scenario, a hypothesis created and explored in the field during the early part of this study.

Dietary shifts are identifiable within comparisons made between the fossil evidence of *Australopithecus* and *Homo* (Aiello and Wheeler 1995, Wrangham et al. 1999, Anton et al. 2014). Archaeologically observed dietary changes have stimulated the creation of a number of theories concerning the changing nature of the behaviour and strategies of Plio-Pleistocene hominins, in particular regarding foraging and resource acquisition strategies (Ungar et al. 2006). Perhaps a complex combination of long-term environmental change and technological innovation drove the development of new dietary adaptations that were part of complex feedback mechanisms involving behavioural, morphological and social changes. The Optimal Fire Foraging scenario fits within this framework and is based on the awareness that most of the Mode 1 benefits identified from a series of 'desk-based thought experiments' could be classed as foraging benefits (Table 2.2). The Optimal Fire Foraging scenario is centred on the notion that: '*wildfire changes the nature and distribution of available resources on the landscape/nutriscape, as well as the dynamics of inter-species resource competition*.

The Optimal Fire Foraging scenario is grounded in Optimal Foraging Theory (well-respected but so far unproven) which on a very basic and simplified level predicts that foragers will always try to optimise behaviour (Bird and O'Connell 2006) and that altering foraging strategies will impact energy budget magnitude (each species will have their own specific preferences to incorporate e.g. preferred foods, dietary breadth, patch choice). The Optimal Fire Foraging scenario predicts that Plio-Pleistocene hominin foraging in a recently burnt environment would enable a significant increase in dietary quality conferring sufficient fitness benefits such that the attraction of the resources offered by recently burnt wildfire environments would be sufficient to act as the driving force for an ever closer relationship between hominin foragers and fire. The Optimal Fire Foraging scenario is based on the assumption that preferential foraging within wildfire burnt environments provided short term foraging benefits that were significantly greater (measurable in terms of harvesting rates or gross yields) than those that would be encountered in the same kind of environment un-burnt. This would allow foraging hominins to raise the quality of their diet and either increase their energy budgets or maintain their energy budgets in times of seasonal resource stress.

Benefits may accrue from factors such as: i) a lot of low grade resources are destroyed by fire raising the relative proportions of medium and high grade resources (in effect transforming lower-ranked patches into higher-ranked ones); ii) resources are transformed by fire (e.g. the creation of ash filled with essential minerals, or 'cooked' food); iii) the visibility and ease of access to certain resources is improved; iv) competition for these resources is greatly diminished due to the effects of fire on the behaviour of competitor species. It may be that the provision of high-grade resources themselves may temporally and spatially increase due to prey mortality from heat and/or smoke, or alternatively it may just be that the handling time decreases making certain foraging strategies more economical. It is conceivable that handling times are so reduced that otherwise uneconomical strategies become economical (e.g. finding and effectively penetrating small mammal burrows).

It is envisaged that over time foraging in wildfire burnt environments and its associated high-ranked patches would have further inured foragers to the dangers of fire and made them increasingly comfortable around fire. The desire to take full advantage of the resources available in a freshly burnt environment would have meant that foraging hominins would have preferentially searched for burning environments to take advantage of the 'window of opportunity' before other members of the scavenging guild deplete resources. Eventually this would have entailed such familiarity with fire that foraging occurs around the fire as it burns thus allowing other 'fire-use benefits' to develop such as the harnessing of smoke to collect honey discussed previously (as per Wrangham 2011).

The Optimal Fire Foraging scenario fares well as a theory against the prescribed criteria. As it is based on Optimal Foraging Theory it fits well with respected evolutionary theory (albeit that a number of criticisms have been levelled of Optimal foraging theory – see Pierce and Ollason 1987 for a critical review). Inquisitive hominin foragers who approached a wildfire burnt environment would be visibly aware of the nature of some of the changes wrought by the presence of fire on the landscape. Successful utilisation of Wildfire Package affordances can provide instantaneous benefits and advantages to foragers that do not result in obligate fire-use but would lead to predicted psychologically closer relationships with fire and that would pre-dispose hominins to search out fires as and when possible even if that was not a regular occurrence. Therefore the Optimal Fire Foraging scenario, when tested against the criteria described earlier in this chapter can be seen as a plausible theory. To provide data and observations to support the Optimal Fire Foraging scenario, and particularly the idea that aspects of the Wildfire Package would provide significant fitness benefits for intelligent foragers', as part of this study fieldwork was designed then implemented in the United Kingdom (on Cumbrian moorland) in March 2012 and subsequently on shrub bushland at the

South African archaeological site of Florisbad in September 2012. Information and data from this fieldwork is found in Appendix ‘A’ but a very brief summary is presented here.

At Florisbad a number of controlled burns were conducted in an ‘overgrown neglected shrub/bush environment’ that had not felt flames for more than a decade. Experiments were conducted looking at the nature of changes to resources including: insect populations, ‘scavengable carcasses’, bird’s eggs, burrows and cryptic animals. In addition an anthropologically ignited wildfire (local rangers suggested the cause to be an electrical fault or discarded cigarette) was observed at the nearby Soetdoring Nature Reserve, which was subsequently visited every two days to take measurements and observations. Overall results can be classified as inconclusive due to a combination of factors (in no particular order of relevance) including the size of the research budget, the attitude of local senior logisticians and the intrinsic nature of fire research but a number of key observations were made that shifted the course of this study from purely physical landscapes to a combination of physical and mental landscapes.

In terms of the direction taken by this Ph.D study, notable amongst these observations was: i) the presence of Vervet Monkeys on a wildfire burnt environment three days after a burn (at the Soetdoring locality); ii) the recording of temperatures in excess of 700^{O}C 15 days after a wildfire (at the Soetdoring locality); iii) the identification of a range of (attractive to hominins) wildfire created resources, but not at the kind of density that would be needed to construct a theory based on their utilisation (especially when modelled alongside the inevitable competition for these resources that would have come from members of the Plio-Pleistocene scavenging and carnivore guilds - which may have been both larger and more diverse than modern guilds in terms of both the number of species and the size of populations); and, iv) distinct differences in vegetation cover before and after a burn (at both sites). However it appears this was not the only study pursuing this line of enquiry as in 2016 another hypothesis was published that bears many similarities to the Optimal Fire Foraging scenario; this early fire theory is called the Pyrophilic Primate Hypothesis.

Pyrophilic Primate Hypothesis

A more complete version of the Optimal Fire Foraging scenario (with more specific impacts on the course of hominin evolution and behaviour) was published in 2016 by Parker et al. called the Pyrophilic Primate Hypothesis. In a similar vein to the Optimal Fire Foraging scenario Parker and colleagues offer a Hypothesis grounded in Optimal Foraging Theory. The Pyrophilic Primate Hypothesis proposes that *Homo* is highly pyrophilic as a direct result of recognising the foraging benefits of adapting to fire-prone environments. These benefits included improvements in efficiency of travel, resource detection and acquisition, and a reduction of food processing costs (Parker et al. 2016) (all of which were personally observed as part of this study during 2012 fieldwork). The Pyrophilic Primate Hypothesis further suggests that fire control in the form of simple landscape burning and purposeful cooking stemmed from these strategies. Parker et al. (2016; 55) make the case that The Pyrophilic Primate Hypothesis '*provides a basal solution*' to some of the issues pervading the Cooking Hypothesis of Wrangham and colleagues.

Importantly for those researchers who favour a deep root of fire the Pyrophilic Primate Hypothesis places the onset of hominin fire relationships prior to the appearance of *Homo* (by unnamed evolutionary antecedents) and specifically states that fire-use enabled *Homo* to emerge as a genus of fire-using pyrophiles (Parker et al. 2016). Parker et al. make a credible job of pulling in and tying together different strands of evidence, including Australasian

Aboriginal anthropological evidence, to produce a coherent model. Parker et al. highlight the benefits of fire-induced removal of obstacles to locomotion and prey detection, and the distribution of ground-level resources obtainable in a wildfire burnt environment (e.g. insects, tortoise, larvae, reptiles, small burrowing animals, seeds, and shallow-rooting tubers) which provide foraging opportunities of interest to hominin foragers. In a similar vein to the Optimal Fire Foraging scenario the visibility of fire to hominins is highlighted with smoke and circling birds acting as indicators of wildfire events. Parker et al. (2016) also highlight the transformative nature of fire and its ability to transform lower-ranked patches into higher-ranked ones also along the lines proposed in the Optimal Fire Foraging scenario.

Where the two hypotheses irrevocably diverge is that within the Pyrophilic Primate Hypothesis Parker et al. (2016; 58) introduce the idea that "*behaviourally flexible hominins could have extended their gains by moving still-burning or smouldering wood and/ or grasses from burned patches across naturally occurring firebreaks…to create new fires*". This would then create new 'higher-ranked patches' which hominins would have been on hand to exploit. In essence Parker et al. 2016 argue that simple fire-controlling behaviour arose quickly and they state that in their opinion even if it only occurred during the dry season the adaptive advantages it provided would produce sufficient positive selective pressure for its incorporation into behavioural lifeways.

The breadth of African fieldwork experience possessed by Parker et al. is clearly visible within the Pyrophilic Primate Hypothesis. Much space is given to a discussion of geophytes and the particular potential of deep rooted species such as *Vigna frutescens*, "*which requires both substantial upper body strength and endurance to collect and the ability to make and control fire to process*" (O'Connell et al. 2002; 433). The case is presented that elephants and other large burrowing mammals leave unconsumed detritus at surface level which would then be ‘cooked’ by landscape fires creating higher ranked resources. The attraction of these resources would in time have led to their purposeful extraction and cooking; in this way the Pyrophilic Primate Hypothesis and the Cooking Hypothesis are linked, with the Pyrophilic Primate Hypothesis acting as a pre-cursor of cooking.

Without data generated through experimental archaeology to identify the level of cooking that grassland wildfire would convey to these particular deep-rooted geophytes doubts do exist about this aspect of the Pyrophilic Primate Hypothesis. These doubts are highlighted because during fieldwork at Florisbad in 2012 a number of experiments were undertaken to look at the amount of cooking that ground-level resources underwent during a grassland wildfire (using culled antelope carcasses rather than geophytes); the answer was surprisingly little (see Gowlett et al. 2017 – in press for further information regarding these experiments). It would be very interesting to see if experimental work on wildfire and the cooking of geophytes supported this line of argument.

Parker et al. (2016: P59) suggest that the onset of hominin fire-use was driven by a desire to reap the foraging benefits provided by the Wildfire Package ‘during periods of aridity-driven grassland expansion…. in the period from 3.6Ma to 1.4Ma’. This incorporates the idea of a deep root for fire beyond *Homo*, but not as far back as the LCA. Indeed Parker et al. are of the opinion that it was not *Homo's* cognition, environmental awareness and physical attributes that enabled relationships with fire to occur, but rather it was relationships with fire that enabled *Homo's* unique and distinctive energy budget, morphological adaptations and strategies to evolve. The Pyrophilic Primate Hypothesis specifically states that: (the) *genus Homo evolved as an actively pyrophilic primate that could not have survived without exploiting the foraging benefits of fire, using it to shape its environment and expand out of Africa into Europe and Asia. This degree of pyrophilia was the result of selection within an* *environment regularly exposed to and altered by burning. Homo erectus….was an obligate pyrophile dependant on fire for survival and reproduction* (Parker et al. 2016; 60).

When assessed against this study's prescribed criteria the Pyrophilic Primate Hypothesis stands up very well against the first two criteria. The Pyrophilic Primate Hypothesis is in accord with established evolutionary theory and plausibly explains the transition from non-fire-users to pyrophiliacs; even stating specific dates for the transition and linking the model in with published palaeoclimatic reconstructions. However the Pyrophilic Primate Hypothesis does not take into account the competition for Wildfire Package resources from other members of Pliocene foodwebs, and the carnivore/scavenging guild in particular. Experimental archaeological studies have not been undertaken regarding the viability of Parker et al.'s '*geophyte cooking supposition*' which appears necessary. Another apparent weakness of the Pyrophilic Primate Hypothesis is that it does result in obligate fire behaviour. Parker et al. (2016) seem to recognise this weakness as they lay out a seemingly coherent case as to why, due to increased mobility in *Early Homo*, the probability of robustly identifying (some of the missing) required fire evidence in the archaeological record remains small. Parker et al. (2016) explain in some detail the absence of hearths, but do not mention the absence of fire igniting technologies from African Asian and Palaearctic archaeological sites despite obligate pyrophilia being modelled in areas with very low fire frequencies.

The Pyrophilic Primate Hypothesis creates linkages between a psychological attraction to fire and fire-foraging opportunities, which appears to work theoretically well and is supported by aspects of resource distribution patterns observed during fieldwork undertaken as part of this study. In addition to the currently unsupportable obligate fire behaviour modelled for the Early Pleistocene, it appears that what is missing, both from the Pyrophilic Primate Hypothesis and from the wider discussion about the onset of hominin fire interactions, is an acknowledgment of the importance of mental landscapes and the ways that adaptations within mental landscapes can have adaptive significance.

As has hopefully been made clear in this chapter no existing model, scenario or hypothesis adequately and satisfactorily explains the initial onset of hominin fire-use, not even the Optimal Fire Forager scenario created as part of this study. In this chapter it was found that no previously published explanation met all of the necessary criteria proposed in this study. Therefore space exists for a new model that mobilises innovative thinking and original concepts in an attempt to adequately and satisfactorily explain the nature of the initial relationship between hominins and Wildfire Package affordances.

Chapter 4 – New approaches to early fire studies

Introduction

So far this thesis has revisited some of the main ideas about early fire and isolated some problems; from the reviews in Chapters 2 and 3 a number of key points have emerged. Perhaps paramount is that no existing hypothesis conforms to criteria set in Chapter 3, and seemingly key issues, such as the strong need for increasingly terrestrial ancient hominins to reduce or mitigate risks, seem to be completely ignored. The transition into *Homo* inevitably involved a restructuring and reorganisation of cognition including risk assessments and environmental relationships evidenced by (amongst others) changes in habitat, group size and structure, trophic level, diet and foraging strategies. While it has been (often) recognised that in primates energy efficiency can be an important evolutionary pressure or driver (e.g. Pontzer et al. 2009), studies that focus on the impact (and effects) of hominin changes in investments in vigilance are scant or non-existent. This chapter explores ecological ideas that are relevant beyond fire studies. In this chapter a proposed new model, the Fear and Flames (FAF) hypothesis is outlined which focuses on the benefits of being able to safely reduce vigilance investments. Later in this study aspects of FAF are tested (Chapters 5 and 6).

FAF is a new hypothesis entirely generated in this Ph.D study to explain the nature of the: i) earliest deliberate opportunistic hominin fire relationships; and, ii) subsequent impacts of a close relationship with Wildfire Package (the sum of wildfire, wildfire burnt environments and wildfire created resources) affordances on the evolution of the niches of our evolutionary lineage. FAF incorporates aspects of the Optimal Fire Forager scenario but also mobilises Wildfire Package affordances hypothesised to be present within mental landscapes. Before FAF is outlined the role of fear as an evolutionary driver is presented as is the evolutionary theory underpinning FAF: Landscape of Fear (LOF) theory.

Landscape of Fear (LOF) theory

The relentless pressure to adequately cope with risks and threats has, in mammals, produced a nervous system that optimises survival actions and controls behaviour (Mobbs et al. 2015). The use of landscapes and environments alters fear levels and impacts in a variety of ways on both the nature of foraging strategies deployed, and the direction of evolutionary pathways (Brown and Kotler 2004); ideas that appear especially pertinent to the study of the very earliest hominin fire-use. A rise in trophic status (as predicted by Vasey and Walker 2001) would have required a significant increase of social carnivore food procurement habits within hominin strategies, necessitating altered (protracted co-evolutionary) relationships with those predators that competed for similar resources (Rolland 2004). This resulted in a situation which was evidently overall advantageous to hominins (proven by their survival and the proliferation of these strategies), but entailed increased vulnerability, especially for dependent juveniles with their prolonged infancy and learning stages (Lovejoy 1981, Rolland 2004).

Risk factors influence the habitat use patterns of a wide spectrum of species (Hernandez and Laundre 2005, Laundre et al. 2014), therefore complex animals (e.g. mammals) can be said to live in a 'landscape of fear'. 'Landscape of Fear' theory (LOF), as set out by Brown and colleagues (e.g. Brown et al. 1999 and Brown and Kotler 2004), is an innovative ecological concept that helps to explain landscape use strategies and decision-making processes displayed by complex animals building upon the (long recognised) existence of different anti-predation strategies (e.g. freeze, 'fight' or 'flight'), which are often the result of multifaceted trade-offs. LOF theory is formulated around the concept that as well as interacting with physical landscapes, complex organisms generate and interact with a mental landscape (termed a 'landscape of fear' or LOF) whose topography is constructed around spatial variation in *perceived* risks and threats (Brown 1999, Brown and Kotler 2004, Willems and Hill 2009, Coleman and Hill 2014). The differing levels of risk that an organism faces, or perceives that it faces, in different habitat types and different environmental conditions determine landscape of fear topography (Hernandez and Laundre 2005, Riginos 2015). Trade-offs between nutrient acquisition and predator avoidance are likely to be affected by the interaction of a range of spatially and temporally variable factors (e.g. abiotic factors such as resource scarcity, as well as the strength of the forager's 'need') (Riginos 2015).

One risk factor, predation, is noted to be a strong selective force that has shaped the morphology, foraging strategies and social behaviour of many species (e.g. Foley 1991, Cowlishaw 1997, Verdolin 2006) and has been specifically cited as the principal driver of primate sociality (van Schaik 1983) (but see Shultz and Dunbar 2007); almost all animal species engage in some form or other of predator-prey interaction (Abrams 2000), hominins included. Predation pressure has in multiple studies been found to significantly impact on the morphology (sometimes termed the 'predator/prey arms race') and behaviour of many species including primates (Cowlishaw 1997); morphological impacts are in addition to social and behavioural impacts. Terrestrial primates live in much larger groups than arboreal species (Hill and Lee 1998); this trend is especially pronounced in species typically found in open habitats (Hill and Lee 1998) as small grouped terrestrial primate species suffer high levels of predation (Shultz et al. 2004). Therefore shifting into more open, high-risk habitats (due to less refuge possibilities) would have substantially increased certain specific predation risks for early hominins (Shultz et al. 2012) thus requiring behaviour or social adaptations to mitigate or cope with increased risks.

Predation pressure by large carnivores has previously been identified as playing a significant role in *Homo's* evolution (e.g. Hart and Sussman, 2002). It is not far-fetched to suggest that hominin morphological and behavioural features will in many ways be highly adapted to reduce the cost of interactions with potential predators and overall predation risks. An important point to note is that within the category of '*ancient hominin predators*' should be included not just animals likely to directly attack hominins, but also potentially aggressive large animals (e.g. elephants and buffalo) as well as aggressive competitors (e.g. hyenas) and dangerous small animals such as snakes and spiders (as per Gerdes et al. 2009).

The correct assessment of risks is vital for the fitness of foragers (Brown and Kotler 2004, Eccard and Liesenjohann 2014). The search for resources can increase the probability of detection by predators, cause prey to forage in areas of higher predation risk, and/or reduce the likelihood that prey will detect a predator as it attacks (Verdolin 2006). This creates a behavioural conflict that needs to be appropriately balanced; increase exposure to risk or miss out on opportunities. The behaviourally mediated effects of predators can be just as important on an ecosystem, and on the overall impact on the niche of prey species, as density-mediated effects (Creel and Christianson 2008, Riginos 2015). In risk-heterogeneous landscapes many animals prefer safer locations over riskier (Cowlishaw 1997); 'risk trade-offs' heavily impact on how an organisms creates its own LOF (Eccard and Liesenjohann 2014).

How external factors and environments alter the level of fear can have major repercussions on lifestyle strategies (Brown and Kotler 2004). For prey species, predation risk is an important foraging cost (Brown 1988) impacting on foraging decisions (Brown and Kotler 2004, Hernández and Laundré 2005); the costs of predation and other mortality risks can be significant and can comprise a forager's largest foraging cost. Seemingly small changes in habitat use can lead to large changes in the nature of risks such as predation (Willems and Hill 2009). With the possible exception of fully fit and healthy mature adult apex predators, while seeking food any forager risks becoming food for another; therefore in response to predation risk successful animals must balance the acquisition of resources and safety. It should be noted that even healthy and mature fit adult apex predators face conspecific and environmental threats and so still need to mitigate risks.

Habitat characteristics, e.g. the availability of cover, can influence the level of predation pressure by altering the lethality (or decision making) of predators which then has ensuing impacts on the vulnerability of prey (Brown and Kotler 2004). In fear driven systems, a predator's largest impact comes via their effects on the foraging strategies and behaviour (e.g. feeding rates) of prey (Brown and Kotler 2004). LOF theory predicts that mobile prey species will, due to predation risks, alter their foraging patterns spending more time in safer areas even at the expense of more profitable foraging opportunities (Cowlishaw 1997, Laundre et al. 2009), in effect often preferring safer food patches over riskier ones (Verdolin 2006); a trend visible in savanah inhabiting baboons (Cowlishaw 1997).

While the direct benefit (and also the direct aim) of anti-predator behaviour is decreased predation risk (Creel and Christianson 2008) predation is not the only cost to prey organisms; other costs include anti-predator behavioural responses known as risk effects. Risk effects can be significant, and in some cases may exceed direct costs (Creel and Christianson 2008). The costs of risk effects can include reduced survival, growth or reproduction; risk effects are the product of a multitude of small actions, individually small effects on fitness accumulate (Creel and Christianson 2008). Primate species can respond to risk effects by exhibiting a range of behavioural adaptations; including changes in habitat use (e.g. retreat to safe habitats

[Cowlishaw 1997]) and vigilance levels (Josephs et al. 2016). Risk effects can bring significant costs that may exist even when predators are non-existent (Creel and Christianson 2008). Within LOF analyses the effects of predators must be categorised into two categories: i) 'direct effects' of predation (incidences of predation); and ii) 'risk effects' of predator activity (which includes perceived or potential predator activity) (Creel and Christianson 2008). Creel and Christianson (2008: 195) suggested that '*as the effort invested in anti-predator behaviour increases, risk effects will increase and direct predation will decline*'. Any strategy that reduces the absolute need for investment in anti-predator behaviour would also result in a significant reduction in 'risk effects' leading to considerable advantages (e.g. increased feeding rates or more social time).

In African savanah ecosystems, with their relatively large concentrations of carnivores, woody cover has often been associated with fear of predation among large herbivores due to the possibility of ambush (Riginos 2015). Investments in vigilance and predator-avoidance have been identified as significantly higher in areas with more woody vegetation (Riginos 2015), which match and support the findings of Hopcraft et al. (2005) that predation rates by lions are significantly higher in areas with more woody vegetation. However confounding factors may exist; variation in woody cover is often associated with variation in foraging opportunities making it difficult to determine whether lightly wooded areas are frequented because of reduced predation risk, superior forage or both (Riginos 2015).

Studies have reached different conclusions. Riginos and Grace (2008) found that, in herbivore communities, higher foraging activity in areas with fewer trees was linked to increased visibility rather than forage availability, however Anderson et al. (2010) found that bovids in the Serengeti congregate on open hilltops due to a combination of reduced predation risk and higher nutrient levels within forage (Riginos 2015). Interestingly, Eby et al. (2013: 335) showed that lions (*Panthera leo*) avoided wildfire burnt areas, and also do not '*preferentially utilise the edges of burnt areas despite the possibility that edges would combine the benefit of cover with proximity to abundant prey*'; this finding accords with the idea that utilisation of burnt areas would decrease the risks faced by ambush predators.

It should be noted here that all of these studies have been conducted on extant carnivore guilds; however Pliocene African carnivore guilds were both larger and incorporated species with a wider array of strategies (e.g. numerous kinds of cursorial hunters) than the modern African carnivore guild (Turner 1990, Werdelin and Saunders 2010). Indeed the fact that the Late Pliocene African large carnivore guild appears to have been broader suggests that a wider variety of niches was available then than now (Turner and Anton 1998). This suggests that the innovative utilisation of new niches may have been one way that a rise in trophic level, a significant trophic repositioning, to join the Late Pliocene African large carnivore guild was achieved. As ancestral conditions are not adequately replicable the case could be made that any study of ancient prey behaviour and strategies that is built upon inferences gleaned from an analysis of modern food-webs and ecosystems is fatally flawed.

In response to this is it argued here that amongst the many Plio-Pleistocene 'known unknowns' (including: the density of specific predators; the spatial distribution of specific predators; the diets and strategies of specific predators; and the Landscapes of Fear of members of the carnivore and scavenger guilds) are the anti-predation strategies deployed by many species of extinct animals including ancient hominins. Many species of prey are viewed in the archaeological and fossil records long after the last appearance of fearsome looking carnivores, which suggests that 'prey' often win their respective 'predator-prey' competitions.

Another point worthy of mention is that for mammals, large brain size reduces predation risk; predators show biases towards, or preference for, small-brained prey (Van Schaik 1983, Shultz and Finlayson 2010, Shultz et al. 2012). Specific reasons for this association are unknown, but species with larger cognitive capacity have been suggested to employ a wider range of escape or defence strategies (Shultz and Finlayson 2010). Increased predation pressure resulting from using more open terrestrial environments may have created adaptive selective forces acting on cognitive changes (including both cognitive restructuring and absolute increases in cranial capacity) in *Homo* antecedents and early members of *Homo* (Shultz et al. 2012). Included in this may have been heightened awareness of both the behaviour and choices of other species (both predators and prey), and the impact on this behaviour of environmental externalities. Ancient hominins may then have been driven to try new strategies to mitigate or cope with increased predation pressures including interacting in new ways with different environments (e.g. wildfire burnt environments) or changing reproductive or social strategies (e.g. reduced inter-birth intervals or larger group sizes).

LOF theory seems an entirely appropriate way to approach the study of ancient hominin fire-use. The Wildfire Package can produce situations with both a broad array of risks to be managed and numerous potentially exploitable opportunities. What is required to successfully exploit Wildfire Package affordances is the knowledge, skills and experience to be able to accurately and dynamically assess the risks and opportunities and then behave accordingly. It is envisaged that the greater cognitive capacity a species has then the more complex its LOF will be (as more variables can be computed and therefore the more multifaceted the options and strategies generated can be). While it is assumed that researchers may never know with absolute confidence how ancient hominins viewed the Wildfire Package and whether they exploited it in the ways that are later proposed in this thesis. It is hoped that the use of LOF theory will illuminate possible benefits and opportunities that may then help researchers reframe the earliest hominin fire relationships.

Landscape of Fear theory and Hominins

Hominin anti-predation strategies are linked to recent evolutionary history (Hahn-Holbrook et al. 2011), therefore the anti-predation strategies of early members of *Homo* may still have included strategies designed to deal with the kinds of predation pressures faced by antecedent species, even if these risks had become significantly diminished. In this study a mismatch between perceived risks and actual risks is seen as being able to provide opportunities for new strategies to develop that can reduce fear levels and associated vigilance investments with potentially significant adaptive pay-offs. To accurately make an assessment of the LOFs of early members of *Homo* an assessment of the LOF of *Homo* antecedents should be considered to gain increased understanding of the foundations from which later species' LOFs are guided. This concept can be extrapolated to suggest that a LOF study of extant humans can create inferences about extinct ancestors. This concept is very useful as the only hominin species whose LOF we can gain a thorough knowledge of is ourselves. This course of action was attempted in this study by creating and deploying an innovative methodology to identify fire-associated LOFs from three culturally diverse communities (Chapters 5 and 6).

While 'predation risk' and 'fear' are well established concepts in animal behaviour literature (Laundre et al. 2010) the LOF concept has, within the literature, not been previously applied to *Homo* antecedents or early members of *Homo*. This is rectified in this study; it is proposed that doing so casts valuable insights into the way that niches were exploited and may significantly help elucidate the origins of hominin fire relationships. Willems and Hill (2009: P547) analysed whether, due to the inherent difficulties of revealing an accurate view of an animal's perception of the distribution of its own predation risks, LOF analyses can be seen as robust; they concluded that while for most mammalian taxa there are fundamental flaws in the methodology they specifically identified primates as a '*notable exception*'.

It therefore seems of fundamental importance to find a place for LOF theory within models attempting to explain hominin paleoecology. Behavioural adaptations developed to minimise risk impact the nature of lifestyle strategies deployed (e.g. foraging strategies, childcare strategies, where social time is spent) (Brown and Kotler 2004, Laundre et al. 2010, Boyer and Bergstrom 2011) and thus will have impacted the direction of hominin evolutionary pathways. It is proposed here that for hominins, through the combined reduction of both direct predation and risk effects, fundamental impacts on lifeway choices are, in part, explainable by LOF theory, LOF adaptation and LOF optimisation (and therefore both morphological and socio-cultural evolution and adaptation).

Central to the study of hominin ecology is an understanding of how individual organisms and communities utilise their environment over space and time (Willems and Hill 2009). Of particular interest here is the notion that the use of landscapes and environments can alter fear levels. LOF theory is based on the precepts that animals are aware of relationships between environmental externalities and levels of risk, and will adjust their behaviour and land-use patterns dependent on a number of factors (e.g. level of hunger, sexual selective forces, needs of kin/offspring) *including* levels of risk. LOF theory however ***does not*** suggest that risk is the only factor influencing landscape uses and foraging choices, but that it is part of a panoply (a wide or narrow spectrum exists depending on species) of factors that influences landscape uses and the nature of foraging choices. As the presence of wildfire on the landscape creates many different affordances and creates/influences a number of risk factors it therefore seems relevant to incorporate aspects of LOF theory into hypotheses attempting to explain the initialisation of hominin fire relationships.

As LOF theory has not yet been applied to hominins and, as hominins are unique in many ways, LOF theory therefore requires a little expansion in some areas; pre-expanded LOF theory is in this study termed 'conventional'. Conventional LOF theory states that instead of foraging in a manner that would solely aim to maximise energy gain or resource acquisition, a forager may accept a lower rate of gain if it also means greater safety from predators (either for itself, and/or offspring or kin) (Brown and Kotler 2004); i.e. trade-offs exist. However when applied to hominins conventional LOF theory has to expand to take into account the enhanced cognitive capacity of hominins and the fact that in species under low predation pressure conspecific threats may be as important, or potentially even more important, as predation risks (Kutsukake 2006, 2009). In this study conventional LOF theory is also expanded to incorporate other (non-foraging based) landscape uses (e.g. nurseries) that are also heavily influenced by attitudes to risk factors (Hahn-Holbrook et al. 2011 *Passim*).

To understand the total effect of predation pressures on past hominin populations, an assessment of the level of direct predation as well as an assessment of the cost and nature of risk effects is necessary. To coherently consider the LOFs of ancient hominins the costs of anti-predator behaviours that may act to reduce direct predation pressure but potentially carry attendant fitness costs (e.g. high investments in vigilance or repeated retreat to 'safety') must be included. Gaining specific understanding of the influence of fear on *extant* animal behaviour is difficult as it can be unclear how to measure the predation risk an individual animal perceives in a particular environment (Searle et al. 2008); obviously it is much more difficult for researchers studying extinct ancient species as no direct field observations exist.

Increasingly nuanced ethological practices and long term observations of animal behaviour have shown that how animals interact with landscapes and the behaviour of other members of their ecosystem (both *inter* and *intra* specific) to a large extent determines the foraging strategies that they 'choose', or are 'programmed', to deploy (Willems and Hill 2009). It is proposed here that the complexity and shape of a hominin's LOF will be determined by a number of factors including: i) the breadth and nature of its emotions; ii) the level of awareness it has of its surrounding environs; iii) awareness of the actions and behaviours of other members of its food web; iv) neural architecture and behavioural relics inherited from antecedents; v) the social structure of its community; vi) the landscapes it has lived within and, vii) its own general life experience. In this study all hominins are assessed as being able to construct and inhabit highly detailed and nuanced LOFs; life experience and observation of our own societies tells us that this is the case with *Homo sapiens*.

While the Late Pliocene African large carnivore guild appears to have been broader and more fearsome than the extant African large carnivore guild (Turner 1990, Werdelin and Saunders 2010) evidence regarding the specific preferential targeting of hominins is scant; although evidence for predation pressure on Australopithecines within faunal assemblages clearly show the impacts of predation (e.g. L'abbe et al. 2015). The archaeological record reveals no obvious specialised predators of hominins, only opportunistic predators (notwithstanding that Berger and McGraw [2007] made a clear case for predation pressure on *Australopithecus africanus* by large raptors). One way of opportunistically hunting is to lie in ambush and grab anything that comes close. Early members of *Homo* may have specialised in ambush predation (Bunn and Gurtov 2014) and therefore would have clearly understood about ambush predation. Open areas created by wildfire would provide reduced opportunities for ambush predation and thus can be modelled as being capable of providing significantly reduced opportunities for hominin predation.

Homo must be viewed as a ‘winner’ in Plio-Pleistocene predator-prey competitions. *Homo* emerges at a time when the African large carnivore guild, in addition to genera that have persisted to the present day (e.g. *Felidae*, *Hyaenidae* and *Canidae*), had a number of other extant genera such as *Homotherium, Dinofelis, Agriotherium* and *Megantereon* (Turner 1990, Petter et al. 1994). Therefore the position taken in this study is that early members of *Homo* (and Late Pliocene *Homo* antecedents) must have had sufficient anti-predation strategies to minimise the effects of predators and their risk effects to maintain populations *provided the right foraging and lifestyle choices were made*.

It is eminently possible that predation pressure in the later stages of the Pliocene helped direct the evolution of hominin lineages as faunal assemblages clearly show the impacts of predation on Australopithecines (e.g. L’abbe et al. 2015). Here the assumption is made (which can be supported with observations on hunter-gatherers and primates) that once a specific danger had been identified at sufficient distance Plio-Pleistocene hominins would have had effective anti-predation strategies (e.g. tool use, throwing or waving of objects, shouting, increasing of size - puffing out of chests) that in the vast majority of cases would cause the predator to desist from its attempt and instead seek other sources of nourishment; this assumption is favoured in the FAF hypothesis. The presumption taken in this study, and it may be a large presumption, is that the Late Pliocene hominin behavioural plasticity (discussed in greater detail later in this chapter) stretched to novel anti-predation strategies that may have involved technological aspects (e.g. bones and bamboo sticks), or even just an enhanced hominin ability to be ‘elsewhere’.

It is further proposed here that the intelligent use of landscapes, including mental landscapes, allowed a suite of behavioural adaptations (with potentially significant adaptive selective pay-offs) specifically designed to minimise contact with 'undesirables' to manifest. If any of the now-extinct genera successfully exploited Wildfire Package affordances then due to the increase in wildfire frequency (assumed to occur in tandem with grassland expansion) then they could perhaps have been expected to have thrived rather than die-out. This suggests that, as with extant large carnivores (Eby et al. 2013), members of Plio-Pleistocene African Large Carnivore guilds did not seek to preferentially utilise Wildfire Package affordances; this provides another exploitable affordance for hominins of the Wildfire Package. Furthermore Boinski et al. (2003) identified that for some foragers predation risk need not necessarily be directly related to predator density but more to the habitat-related behaviour of the predator.

This insight has enormous impact on FAF as this can potentially mitigate critique of FAF in the form of 'the Plio-Pleistocene African Large Carnivore guild was broader than the current guild – hominins inhabiting open areas (e.g. a wildfire burnt environments) would be at greater risk not lesser risk'; this would only be the case if predators wanted to hunt in open environments. The stance taken here is that the acknowledgment of the presence of a broad African Large Carnivore guild, some of whom may have competed directly with hominins for resources (or who viewed hominins as a resource to exploit), should not overly constrain researchers views of hominin landscape exploitation. Yes acknowledge the presence of the broad African Large Carnivore guild, but also acknowledge the skill and adaptability of the hominins to carve successful niches. What also needs to be explicitly acknowledged is the potentially temporal dimension of ancient hominin Wildfire Package interactions. It is not possible to be one hundred percent confident that all members of ancient carnivore guilds would have avoided wildfire burnt environments, particularly during later stages of re-growth when nutritious new shoots would attract herbivores to the area. This is assumed would also attract carnivores (as per Eby et al. 2013); however carnivore activity is not just related to the density of prey but also to the perceived chance of a successful hunt (Eby et al. 2013). Therefore there appears to be a lot of different variables at play here, but LOF theory is well able to cope with these ideas on both short and long timescales; constant risk assessments enable strategies to develop as risk factors change.

As requirements to maintain high levels of vigilance or frequent retreats to safe habitats can significantly impact on energy budgets and therefore the overall biological fitness of an organism or species (Creel and Christianson 2008, Willems and Hill 2009) in this study it is proposed that the study of Plio-Pleistocene hominin LOFs can contribute significantly to the study of the initial onset of hominin fire-use. It is further proposed that LOF adaptations are capable of impacting on the nature of hominin communities, (i.e. social and foraging strategies) which appear to significantly differ between *Homo* and *Homo's* antecedents (Anton et al. 2015). This suggests that LOF adaptations were potentially partly responsible for driving or enabling the emergence of *Homo*.

LOF adaptations may have been particularly beneficial when '*a threat is possible but as yet no presence of danger has been detected*' (Mobbs et al. 2007); this is known as the 'pre-encounter phase' (see Fanselow and Lester's 1988 'threat imminence continuum') which has been identified as being characterised by the deployment of precautionary behaviours in the form of increased vigilance such as heightened alertness and environmental surveillance (Mobbs et al. 2015). The 'pre-encounter phase' characterises what in this study is the assumed state of much of the ancient Plio-Pleistocene hominin day. Pertinent to this study Mobbs et al. (2015: 8) identified that during pre-encounter "*the ability (of an organism) to* *make accurate predictions concerning potential threats is highly adaptive and enables it to flexibly change behaviours to protect itself from risk*". This adaptability is highly pronounced in modern humans as human cognition specialises in improvisation (Duncan 2001). Humans have also evolved unique methods of learning; for example human children learn from others' mistakes but nonhuman primates do not (Sherwood et al. 2008 *Passim*).

Traces of 'Palaeolandscapes of Fear' (PLOFs) within modern LOFS

The discipline of evolutionary psychology suggests that some vestiges of our evolutionary past remain as 'behavioural relics' within human neurological architecture (Coss and Charles 2004). 'Behavioural relics' are behaviours or traits alleged to have had adaptive significance in the evolutionary past which have persisted intact to the present day in the absence of any obvious sources of natural selection (Coss and Charles 2004). Behavioural relics from *Homo's* evolutionary past have been observed in a number of non-fire related studies conducted on how humans react to their natural environments (e.g. Kaplan and Kaplan 1989, Han 2007 *Passim*). Some of these studies have been conducted using similar methodologies to those deployed in this Ph.D (see Chapters 5 and 6) to study subjects like: the impacts of nature experience on human cognitive function and mental health (Bratman et al. 2012); precocious knowledge of anti-predator refuges (Coss and Moore 2002); and, human relationships with aspects of the environment such as tree shapes (Sommer 1997, Lohr and Pearson-Mimms 2006, Han 2007). Research has shown that modern humans can exhibit aesthetic, emotional, and physiological responses to scenes and other sensory stimulations of natural landscapes (Lohr and Pearson-Mimms 2006). As behavioural relics are recognised within human psychology and cognition (notwithstanding the issues laid out previously in Chapter 2) the existence of behavioural relics relating to anthropogenic fire-use strategies within modern populations of *Homo* is, on a theoretical basis, *in this study viewed* as eminently plausible and not contradictory to established evolutionary theory.

It is proposed here that if fire related behavioural relics are identified in the LOF of modern humans then these could be used to examine much earlier attitudes to, and relationships with, fire; this would include the initial uptake of anthropogenic fire-use strategies; which what would have been a very important step, irrespective of when it occurred, in the evolutionary history of *Homo*. It is proposed here that the presence (or lack of) fire-related psychological behavioural relics could provide important ways to approach FAF.

Clearly, one of the most important requirements in testing the FAF hypotheses is the ability to relatively accurately view aspects of ancient mental landscapes; termed 'palaeolandscapes of fear' (PLOFs). Viewing ancient PLOFs requires acknowledging and facing many formidable obstacles not least the many 'known unknowns' of hominin behaviour and morphology, in addition to the temporal and spatial vagaries of the palaeoenvironmental and palaeoecological records (discussed previously). For example at 3.5Ma, despite decades of multi-disciplinary research using a complex range of methodologies, it is still not clear exactly how hominins moved, foraged or constructed their societies.

Complex behaviours such as vertebrate habitat preference are genetically determinable (Falk and Balling 2009). Actually viewing ancient hominins PLOFs will prove problematic for a number of reasons. To date LOF theories have been developed and observed using field studies on extant organisms. While it has been a relatively straightforward exercise to construct a theoretical platform that highlights the possibility that an ever closer relationship with fire would lead to significant changes in hominin LOFs and therefore evolutionarily significant fitness benefits that could impact on the nature and direction of hominin evolution, robustly testing this theory will prove to be much more difficult. Put simply, inferences on an ancient hominin PLOF are more difficult to produce, and thus more difficult to defend, than inferences on the LOF of an extant species or community.

Theoretically PLOFs of ancient hominins could be partially reconstructed purely from analysing excavated archaeological material (e.g. faunal assemblages). However one way to strengthen the construction of an ancient hominins' PLOF would be to combine this data with data from modern humans. If fire was a key factor in the evolution of the genus *Homo* and was a key construct of the entire *Homo* niche then, despite recent significant changes in hominin lifestyles and strategies some vestige of this may be visible in the attitudes and relationship of modern extant populations of *Homo* and fire. It is hoped that the combination proposed here of using archaeologically and palaeoanthropologically garnered information in combination with data from current populations about present attitudes to fire will result in greater resolved inferences regarding ancient hominin 'Wildfire Package related PLOFs'.

Hominin Learning

While the nature of inherited neural architecture will significantly impact fear and risk based decision making it is well recognised that one way that extant humans react to stimuli is through associative learning which provides quick and decisive actions based upon experience (Mobbs et al. 2015); there is no reason to believe that within the hominin lineage this is a trait unique to *Homo sapiens*. Mobbs et al. (2015) make the case that a crucial component of our neural architecture is the ability to continually update and modify responses to stimuli through learning; this is potentially very important to early fire researchers as it helps to explain how intelligent foragers could exploit Wildfire Package affordances to gain adaptive pay-offs. Mobbs et al. (2015) further highlight the way that both soft-wired higher order systems such as 'event prediction' and basic associative systems including hard-wired responses are modulated by associative learning.

To ensure group survival Rolland (2004) highlighted the need for a setting for young hominins that favours the transmission of knowledge and behaviours through prolonged learning and sharing of technical, socio-economic, and cognitive repertoires. In this study the significance of Wildfire Package affordances to infants, juveniles, nurseries and caregivers is specifically highlighted (Chapter 7). One important reason why 'infants and juveniles' have been identified as an important demographic group to the uptake and stabilisation of hominin fire-use is by placing infants and juveniles within wildfire burnt environments this would significantly increase hominin exposure to Wildfire Package affordances when behaviour is most plastic, when curiosity is expected to be heavily selected for and when epigenetic alterations to cognition occur (Power 1999, Oudeyer and Smith 2016). Curiosity is perhaps an important hominin trait to discuss and has been defined as '*an epistemic motivational mechanism that pushes an organism to explore activities for the primary sake of gaining information'* (Oudeyer and Smith 2016: P2)

Having personally witnessed the high levels of infant and juvenile curiosity that seems a feature of wild apes (habituated gorillas [Mgahinga NP, Uganda] and chimps ([Kabale Forest NP and surrounding environs, Uganda]) and knowing the importance of early environmental relationships in humans (e.g. Power 1999) it seems sensible to suggest the possible significance of infant and juvenile curiosity to FAF. With respect to the earliest initial interactions between hominins and the Wildfire Package, infant curiosity would enable many of the Mode 1 fire opportunities (such as those laid out in Table 2.2) to be realised and actualised. Learning is not a passive experience; infants select and create these experiences (Oudeyer and Smith 2016); the desire to learn can generate spontaneous exploration and intrinsic rewards (Gottlieb et al. 2013). Infant and juvenile learners use play as a way to harness the complexity of their learning environment through exploration (Oudeyer and Smith 2016). Oudeyer and Smith (2016: P9) even state that '*the dominance of curiosity in the human motivational hierarchy may be fundamental to the emergence of humans' unique wide-ranging domain-specific knowledge'*; this links neatly with fundamental FAF tenets.

Feedback-based learning has been previously considered inappropriate to the task of acquiring information about major risk factors (e.g. the behaviour of predators and fire) since, particularly for children, the costs associated with such learning would be prohibitively high (Barrett 2005, Fessler 2006). The proclivity for juvenile curiosity of fire has been previously scientifically observed as Murray et al. (Murray et al. 2015 *passim*) note a number of studies that show that children and adolescents appear to be particularly interested in fire and express high rates of fire-play. For example, Kolko et al. (2001) conducted a three-year longitudinal study (N = 162, mean age = 9.5 years); by the end of the study < 70% of participants had at some time played with matches or set a play fire. Perrin-Wallqvist and Norlander (2003) observed in a study of 18/19 year old Swedes (N = 95) that the principal motives for childhood fire play were curiosity, entertainment, and excitement seeking; a high proportion of subjects reported being fascinated or drawn to fire.

While Murray et al. (2015: P206) agree with Fessler (2006) that '*pure trial-and-error learning is likely not appropriate*' Murray et al. suggest that the specific properties of a fire-learning machinery should be similar to those of a predator information acquisition system; information will be rapidly acquired and learning will occur without extrinsic motivation.

Fessler (2006) adapted for fire-use 'Barrett's (2005) five-featured characterisation of the human information acquisition system dedicated to learning about predators'. Fessler (2006) highlights how the design of human neural architecture supports observed modern fire framing and provides a coherent pathway for aspects of observed modern relationships. Fessler's model is briefly summarised here:

1. Learning can be expected to occur without extrinsic motivation. Children are expected to be spontaneously interested in and curious about fire.

2. Fire is predicted to have extremely high salience. Information is expected to be acquired rapidly; perhaps even from a single exposure (Mobbs et al. 2015 *Passim*)

3. Others' fire-knowledge can be expected to play a valuable role; socially-transmitted information constitutes a valuable resource for fire-learners

4. The information acquisition system can be expected to employ biases or prior structures that guide learning in the specified domain.

5. Acquisition of procedural knowledge may be achieved in part through the operation of dedicated mechanisms that serve to generate relevant experience in a safe context. Manipulation of embers or small fires may provide a means of acquiring relevant experience in a more safe setting.

If Fessler's (2006) characterisation of fire-learning is correct and is a relic of ancestral relationships, then in line with this thinking, those hominins who were most curious about the Wildfire Package and the impacts of wildfire on physical and mental environments can be viewed as uptaking fire-related behaviours quickly and potentially benefitting most. If play, formative learning and spontaneous exploration were to happen within a wildfire burnt environment, surrounded by various Wildfire Package affordances, then it would have very significant implications for the modelling of the earliest hominin fire interactions. It would help to explain how behavioural adaptations were discovered, spread and stabilised within a population in a non-teleological way.

Curiosity is stimulated by interest, and what is interesting depends on what one knows and what one does not know (Oudeyer and Smith 2016). Human interest seems to be engaged by what is just beyond current knowledge (Oudeyer and Smith 2016); hominin utilisation of wildfire burnt environments for the foraging benefits (see Optimal Fire Foragers' Hypothesis) or for the vigilance and stress reduction benefits (as later proposed by FAF) would provide ample opportunity for physical and mental engagement with the impacts of fire on the environment. Play, learning and exploration would broaden and strengthen environmental knowledge. Those infants and juveniles who had played and explored in wildfire burnt environments could confidently be expected to return to the same environments later in life.

Murray et al. (2015) place a heavy reliance on socially transmitted information as a valuable form of hominin learning. While direct threat encounters that do not result in death or predation will provide valuable information to inform future decision making, observing other people having these encounters will also help individuals to make quick and decisive actions based upon their own experience; it has been previously observed that socially transmitted fear is critical to non-human primate learning (Mineka et al. 1984, Mobbs et al. 2015). The combined information learned through processing our own experiences and personal observation can provide a broad platform for decision making and can provide the basis for the creation of novel ways to reduce future risks and threats. It is proposed here that if over time these behaviours were repeated often enough and were sufficiently beneficial (i.e. large adaptive pay-offs) then they themselves would eventually become part of the hard-wired neural architecture. If this started to happen in the Pliocene or Early Pleistocene, before significant hominin encephalisation had occurred, then it would be currently considered as phylogenetically ancient and would not only underlie the more recent layers of neural architecture but would have impacted on the nature and formation of this new architecture. The idea that fear can act as an evolutionary driver or adaptive selective force is not a new concept and underlies much previous work undertaken on predator prey dynamics.

Fear as an evolutionary driver

'In animals fear is real, measurable and, drives the actions of prey in response to predation risk' (Laundre et al. 2010: P2). In the literature fear and anxiety are considered 'motivators' and have been defined as '*emotional states that are induced by the perception of any actual danger (fear state) or potential danger (anxiety state) that threatens the well-being of the individual, and which are characterized as a feeling of insecurity*' (Gray 1971). Fear is an emotion induced by a perceived threat causing a change in brain and organ function and, when faced with traumatic events, ultimately a change in behaviour (e.g. running away, erect hair follicles, hiding, urination). It seems apparent that the major adaptive function of fear responses and neural circuitry is to respond to all external stimuli that can potentially damage or harm an organism (Panksepp 1982). A prime objective is to reduce surprise and optimise reactions by the deployment of prevention strategies in which the organism manufactures safe environments (Mobbs et al. 2015 *Passim*); this can be viewed as a form of niche construction.

Fear is entrenched within the hominin genome within the nature and behaviour of the autonomic nervous system; encoding for the production of hormones, pheromones and other behavioural stimulants and signallers preserves genetic responses (Olsson and Phelps 2007). Security motivation is thought to differ from other motivational states in that '*it must be* *terminated by endogenously generated satiety signals*' (Hahn Holbrook et al. 2011: P1057) as 'a landscape' is not capable of providing conclusive safety cues regarding the presence or not of potential hazards (as per Szechtman and Woody 2004). Panksepp (1982) suggested that the generation of emotions can be traced to specific hard-wired neural circuits in the visceral-limbic brain that engender and stimulate a suite of diverse and adaptive behavioural and physiological responses to environmental challenges.; key elements of the risk appraisal network include the prefrontal cortex, amygdala, hippocampus, and bed nucleus of the stria terminalis (Hahn-Holbrook et al. 2011 *passim*, Mobbs et al. 2015). Mobbs et al. (2015: P1) state that '*responses to threat are underwritten by an interconnected neural architecture that extends from cortical and hippocampal circuits, to attention, action and threat systems including the amygdala, striatum, and hard-wired defensive systems in the mid brain'* while Olsson and Phelps (2007) suggest avoidance behaviour appears mediated by input to the basal ganglia from the basal nucleus. However the (polygenic) genomic substrate of threat-detection has not yet been sufficiently deduced (Boyer and Bergstrom 2011); gaining a more complete understanding of how unique features of hominin behaviour are mapped onto evolutionary changes in neural structure is very challenging (as per Sherwood et al. 2008).

The interconnected medial prefrontal network plays an important role in the active experience of emotion (Mobbs et al. 2015); prefrontal processing also enables the forecasting of future outcomes, and relays these interpretations to the amygdala, which functions as an 'alarm' complex to relay signals of threat (Baxter and Murray 2002, Bechara et al. 2000, Hahn-Holbrook et al. 2011). The hippocampus is thought to receive inputs from the amygdala prerequisite to the formation of contextual emotional memories; identified as a vital function for deriving cues of potential danger (Hahn-Holbrook et al. 2011 *Passim*). In higher primates research across species highlights the critical role of the amygdala in fear conditioning

(Olsson and Phelps 2007), hypothalamus and periaqueductal gray regions (Mobbs et al. 2015), and may incorporate discrete pathways from the amygdala-hypothalamus and periaqueductal gray for different types of fear stimuli (Gross and Canteras 2012). This is because threat detection systems are most likely domain-specific with many different systems geared to different kinds of threats (e.g. from predators and conspecifics) which will each have different cues and stimuli (Boyer and Bergstrom 2011). Indeed potential danger (e.g. predator proximity) and imminent danger (e.g. predator attack) may elicit very different behavioural and psychobiological processes (as per Woody and Szechtman 2011).

Immediate threat responses (e.g. freeze, flight or fight) are the most primitive responses and are hard-wired spinal reflexes that provide rapid reactions to threat (Lee et al. 1996). Interestingly Mobbs et al. (2015: P16) speculate that relationships visible in the interconnected medial prefrontal network '*suggest that complex neural systems are connected to older defensive systems*'. Due to the complete lack of ancient hominin fossilised brain material researchers are much more cognisant of the size of ancestral species' brains rather than their internal structure, with evidence for hominin neurological traits limited to what can be gleaned from endocranial casts and archaeological evidence (Mithen 1996). Speculation by Mobbs et al. (2015) does suggest that aspects of neural networks responsible for fear based responses and psychobiological relationships with environmental externalities in modern humans may have very ancient origins. It is proposed here that behavioural relics of important adaptive ancestral behaviour (i.e. those that generated significant adaptive pay-offs) are present within extant neural networks, and that these behavioural relics can be analysed to observe and study the nature of these potentially evolutionarily important ancestral behaviour. This proposition is supported by the fact that the fear based midbrain regions briefly discussed previously are involved in phylogenetically older adaptations (Price and Drevets, 2010), an idea discussed in greater detail by Mobbs et al. (2015).

Internally, fear can be measured via changes in corticosteroid levels stimulated by nervous impulses; outwardly fear is measurable by investments in vigilance (Laundre et al. 2010). The fear response serves survival by generating appropriate behavioural responses (Olsson and Phelps 2007). Individual animals with inadequate fear response mechanisms may not survive to pass on their genes. Fearfulness is considered to be a personality or temperament trait defining the general susceptibility of an individual to react to a variety of potentially threatening situations (Boissy 1995). Fear has previously been cited to explain the use of caves and trees as refuge for members of *Homo* (e.g. Hart and Sussman 2002).

Habitat types have different risks and therefore require different strategies and investments in vigilance (Brown and Kotler 2004). The way in which higher animals exploit their spatial environment has been identified as being driven primarily by the distribution of resources and the presence of predators and other risk factors (Mangel and Clark 1986), both of which can influence foraging strategies (and therefore also selective forces) in different ways (Willems and Hill 2009). In any given situation risk assessments by complex organisms will lead to decisions regarding which behaviour to deploy. Threatening stimuli cause changes in behaviour and the orientation of attention toward the threat (Blanchard et al. 2011); the environment in which this happened may then become associated with this threat (Mobbs et al. 2015). Fear of a locality can be expressed in a number of different ways; e.g. by locality avoidance or increased autonomic arousal when approaching it (Olsson and Phelps 2007).

The level of 'fear' felt by the presence of these risks (or perceived risks) will be impacted by an organisms' genetics as well as its own life experience (Boissy 1995). An individual's LOF will be dependent on the complex interplay of a large number of inherited (genetic) and acquired (experiential) factors (Boissy 1995) (including, but not limited to: cognitive capacity, trophic level, cultural capacity, evolutionary history and personal life experience). Therefore different individuals and groups within any species may exhibit different psychobiological responses to environmental challenges or fear stimuli (with some species having a stronger genetic 'footprint' than others e.g. species of shoaling fish), but where the costs of making the wrong choice are very high (e.g. predation) homogeneity of response is expected (Coleman and Hill 2014). Results and conclusions from a LOF study may not be transferable to other organisms or species (which by definition will occupy different niches). The LOF generated by two similar organisms living in the same locality (but with different niches) can be very different (Coleman and Hill 2014).

Fear has intrinsic survival value in wild animals within all environments and climatic zones (Boissy 1995). The life expectancy, and therefore in most cases biological fitness, of an animal is increased if it reacts successfully to sources of danger. In ancient hominins, like in most other organisms, the most important threats of injury encountered during its lifetime would have come from predators and competing or attacking conspecifics (Boissy 1995, Hahn-Holbrook et al. 2011). Thus considerable interest exists amongst researchers into the evolution and nature of both anti-predation strategies and ways of dealing with conspecific threats. LOF adaptations may be linked to both. Inappropriate anti-predation strategies can produce rapid and often disastrous consequences (Blanchard and Blanchard, 1990); therefore these strategies are very often affected by strong selective pressure. Anti-predation strategies can be deployed even when the fear of predation is only 'potential' rather than 'actual'

(Boissy 1995, Creel and Christianson 2008) and thus can be energetically costly if levels of fear are high, and fear responses common.

Fear is expressed along a spectrum depending on the nature and strength of the stimuli. Some researchers have tried to differentiate fear from anxiety by proposing that fear results from identifying the presence of a highly imminent or tangible threat (Mobbs et al. 2015), but when a stimulus is intangible or temporally or spatially remote anxiety occurs (Bouton et al. 2001). The strength and proximity of the fear stimulus will impact on the nature of the response deployed. The first response to a stimulus may be (an increase in) vigilance, thus increasing attention and concentration on potential threats.

Vigilance

Animals will associate a particular context, environment, activity or event with risk or threat and will attempt to mitigate perceived risks (Mobbs et al. 2015); this will manifest in the form of fear. Vigilance is one way to manage ‘fear’ and plays a key role in primate foraging strategies (Cowlishaw 1997, Brown 1999). Vigilance occurs when a forager switches from any activity (e.g. harvesting food or grooming) to attempting to detect predators. As prey rarely operates with perfect information on the whereabouts and activity of predators, constant maintenance of a level of fear of predation and thus investment in vigilance is required (Brown et al. 1999). Vigilance can reduce predation risk but also has a price (e.g. reduced feeding rates). The principal cost of vigilance is often ‘opportunity costs’ (e.g. foraging) measured in time, with the most common trade-off occurring between vigilance and foraging (Brown 1999, Ciuti et al. 2012). Each forager must invest sufficiently in vigilance to negate or mitigate predation risk. Complete attention to foraging tasks may enable yields to be maximised but the price would be total ignorance of the approach of predators, and vice versa; trade-offs are required. Optimal foraging theory suggests that (appropriately) minimising the costs of trade-offs will provide significant adaptive selective pay-offs.

A conflict between vigilance and foraging activity has been observed in chimpanzees and baboons; vigilance levels are lower during foraging than resting (Kutsukake 2006) which may not match up with respective threat levels. As vigilance varies with risk, increasing investments in vigilance should improve threat detection, but not without cost (Treves 2000). If a forager does not sufficiently invest in vigilance then (if predators exist) the chances of predation will be increased; investing the correct amount of resources in vigilance is very important to overall biological success and is here considered a significant adaptive selective pressure. The presence of threats and risks and the need to invest in vigilance behaviour and strategies has had significant impact on the nature and form of the social structures of many different species. This can occur through many different processes including sharing the cost of vigilance, risk dilution or being able to deploy group anti-predation strategies (Mobbs et al. 2015 *Passim*); ancient group-living hominins may have significantly benefitted from these strategies in similar ways to some species of modern apes (e.g. panins).

It can be assumed that for higher primates slow growth rates and long per generation times do not allow for the underestimation of the risk of predation, as on an individual and species level the costs of predation are high. However overestimating the chances of predation will result in a loss of fitness as too many resources are invested in vigilance; therefore investing correct amounts of resources in vigilance is a key part of any foraging strategy. Knowing when to invest in vigilance is a key skill as early detection of risk allows for the consideration of different mitigation strategies (Mobbs et al. 2015). Minimising investments in vigilance without increasing risks should provide significant benefits to foragers in the form of adaptive benefits (Brown et al. 2004). This premise is very important in this study. In this study it is proposed that **Wildfire Package affordances, including behavioural changes to animals (e.g. predators and conspecifics) created exploitable opportunities within the ancient hominin LOF to intelligently improve biological fitness by reducing risks without increasing vigilance investments (possibly even reducing them in some ways).**

Even when vigilance is applied to mitigate the risk of predation a forager's giving up density (GUD) should increase in risky situations. A GUD is the amount of resources (in units of exploitable resources per unit area) at which a forager decides that it is no longer worth foraging on that patch and decides to switch to either another patch or a different activity. A GUD depends on the predation cost of foraging determined by a combination of predation risk, availability of food and an organism's or community's energetic or nutritional state (Brown and Kotler 2004). Frightened prey will have higher (giving up densities) GUDs as they sacrifice food for safety (Brown 1988). LOF theory predicts that in safe circumstances resources and foraging opportunities can be more thoroughly depleted resulting in smaller GUDs (Brown and Kotler 2004). By following this line of reasoning a forager investing heavily in vigilance would require an increase in resource abundance to maintain harvesting rates. When viewed from an opposing angle, a forager that does not have to invest heavily in vigilance can happily forage in a resource poor environment (previously experimentally observed in a population of wild baboons [*Papio cynocephalus ursinus*] by Cowlishaw 1997).

Modelling vigilance levels and resultant benefits is problematic. To cope with the fact that fear manifests along a gradient from attention to extreme terror (Darwin 1871) different forms of vigilance exist with different levels of investment (Mobbs et al. 2015). The level of attention invested in vigilance will impact on the cost of the vigilance behaviour; heightened vigilance can be extremely costly in terms of energy invested and/or opportunity costs (Eysenck 1992). When vigilance occurs without conducting another activity (e.g. chewing food) this should be classed as ‘induced vigilance’ or ‘fully focussed vigilance’ (Blanchard and Fritz 2007); as foraging opportunities are lost this carries a high cost. Fully focussed vigilance is more costly than ‘vigilance while maintaining the activity’ (e.g. chewing or grooming), known as ‘routine vigilance’ (Kuijper et al. 2015); primates are known to deploy routine vigilance for a wide variety of reasons (Pays et al. 2012).

Even if all potential risks were to reduce to zero, for a primate to reduce investments in vigilance to zero would not necessarily be beneficial. Other potential benefits of investing in vigilance includes gaining information about other aspects important to a successful primate life such as: distribution of resources, social environments, feeding competition, travel planning, conspecific threats, as well as the nature and formation of social interactions and alliances (Kutsukake 2009, Gaynor and Cords 2012). Vigilance behaviour in wild chimpanzees is heavily determined by the presence and actions of conspecific factors not only predators (Kutsukake 2009). Infanticide is a problem in most primate lineages (Boyer and Bergstrom 2011 *Passim*) and is evident in the worries of modern human parents suggesting it has been a major issue in the hominin lineage. In 1982 in the US strangers accounted for less than 3% of the non-natural child deaths caused by automobile accidents, yet despite the disparate frequencies parents worry about these two potential risks to children at comparable rates (Hahn-Holbrook et al. 2011 *Passim*).

While ecologists have long recognised that animal space-use is primarily determined by the presence of risk factors (e.g. predators) and the distribution of resources (Abrams 1984, Willems and Hill 2009) literature searches have failed to identify quantitative studies conducted on extant species of the full range of benefits accrued from vigilance investments (or the specific costs of the trade-offs involved); this makes modelling optimum vigilance levels of extinct species even more difficult. Mathematically quantifying certain ecological relationships with any precision is almost impossible, has not been attempted in previous Landscape of Fear studies and is not attempted in this study. In this study adaptive selective pathways are highlighted but mathematical projections of adaptive selective pay-offs or biological fitness benefits are not presented. Ethological observations underpin modeling.

Field observations on omnivorous savanah dwelling primates can provide good opportunities to infer behaviour and decision making of *Homo* antecedents and thus may help researchers to visualise and model certain strategies and relationships (however see the limitations and weaknesses of this approach outlined in Chapter 2). However, even with the use of primate analogues, calculating the specific size and scope of adaptive pay-offs is not feasible as very large scale (multi group) and multi generational (potentially taking many decades) studies with groups in isolation (including control groups) are required to accurately observe the impacts of a specific strategy or adaptation. In this study the focus is on showing pathways and placing the tenets of FAF within a nexus of other adaptive selective forces and archaeologically observed traits that are the background to the emergence of *Homo*, and not on the results of mathematical models requiring difficult to support equations and potentially spurious inputs (e.g. Sorensen 2009).

The Fear and Flames Hypothesis

Introduction

As was highlighted in Chapter 3 no existing hypothesis conforms to all three of the criteria for accepting the viability of an early fire theory prescribed in this study. Partly to resolve this issue as part of this study a new hypothesis has been formulated termed the Fear and Flames Hypothesis (FAF). FAF argues that a more nuanced viewpoint looking specifically at the 'impact of wildfire on landscapes and the nature of available resources' provides new insights into how and why ancient hominins evolved as they did; resulting in a genus that migrated 'out of Africa' so spectacularly. FAF is centred on the notion that it is not only the physical aspects of Wildfire Package affordance exploitation that could have provided hominins with significant adaptive pay-offs; an appraisal of benefits obtained by adaptations within 'mental landscapes or environments' may provide some new answers and a new perspective.

FAF incorporates aspects of the physical foraging benefits laid out in the 'Optimal Fire Forager' and 'Pyrophilic Primate' hypotheses (Parker et al. 2016) in addition to the benefits of reduced risks and attendant reductions in vigilance investments enabled by Wildfire Package affordance exploitation. Energetic benefits are suggested to accrue from a number of different pathways. Including by: reduced time spent searching and handling resources (as per Parker et al. 2016); the increased nutrient availability due to heating or 'semi-cooking' of food items (as per Wrangham 1999); taking advantage of changes to landscapes and foodwebs created by the presence of wildfire on the landscape (as per Herzog et al. 2014). Additionally benefits may be provided by other Wildfire Package affordances such as reduced parasite loads due to tick/flea/parasite mortality caused by fire/smoke. However in this study not all affordances are focused upon in detail; in this study the nature of, and adaptive selective pay-offs generated by, Wildfire Package vigilance reduction affordances are focused upon.

The FAF hypothesis proposes that the Wildfire Package creates a broad range of affordances for hominins to beneficially exploit. Foraging or physical benefits would have provided selective advantages to foraging hominins which would have been further augmented with psychological benefits, in the form of stress and fear reduction, obtainable through intelligent use of mental landscapes. FAF further proposes that psychological adaptations were necessary to fully benefit from physical benefits and that it is these psychological adaptations that may illuminate the nature and timing of the earliest preferential hominin fire interactions. It is argued here that the increased stress related to a combination of (as per Gamble et al. 2014) increasingly terrestrial lifestyles within an ecosystem inhabited by an (relative to modern times) expanded African large carnivore guild, and the increased stresses associated with larger group size (e.g. maintaining relationships) would have meant that stress reduction opportunities would have been both highly beneficial and highly sought after by ancient hominins in the period 3.5-2.0Ma. Increased group size associated with terrestrial living (Hill and Lee 1998) is emotionally costly and creates stress (Shultz et al. 2012); stress hormones like cortisol cause wear and tear on hominin bodies and minds and can be especially disruptive to females through the destabilization of hormone cycles (Gamble et al. 2014).

An understanding of FAF requires viewing the Wildfire Package as containing a complex package of exploitable benefits; many are physical but others are only available within mental landscapes. While a hypothesis needs to be concise and specifically designed to fit the data it is trying to explain, in this case, in a similar vein to ‘regional traditions’ observed in chimpanzee culture (Whiten et al. 2001, 2007), the relative importance of different aspects of FAF would perhaps differ spatially and temporally in nature. In addition to regional traditions the individual nature of each dynamic wildfire event means that the suite of opportunities created, and therefore the strategies deployed to take advantage of Wildfire Package affordances, will differ greatly. Potential benefits will be specific to individual fire events and will change over time. While many benefits may be delayed (discussed at length later in this chapter – e.g. highly nutritious plant re-growth), potential immediate fire benefits (some of which are demonstrated by avian fire-followers [Bouwman and Hoffman 2007]) include:

i) Cryptic animals (e.g. tortoise) become much more easily visible

ii) Reduced handling times as many potential resources become more visible - such as fallen fruits nuts and seeds, tubers, birds' eggs, animal burrows.

iii) Immediate fire mortalities (and incapacitated prey) caused by fire and/or smoke

iv) Intelligent general utilisation of habitat-related behaviours of other animals (including from potential prey and predator species as well as other members of the foodweb)

v) Using smoke and/or the panic induced by the presence of wildfire on the landscape to improve or increases ambush predation opportunities

The last point perhaps needs some support from the literature. Palaeoanthropology is littered with big ideas (e.g. Savanna hypotheses) that can superficially appear credible but are not necessarily evidence-based. The emergence of lithic technology by 3.3Ma has often been interpreted as a correlate of increasingly recurrent hominin acquisition and consumption of animal remains (Ferraro et al. 2013) even though other uses for lithic technologies have been suggested (e.g. Mercader et al. 2007 and their argument for lithics arising as a need to process vegetation). What is clear is that for at least some groups of ancient hominins by ~2.0Ma Ferraro et al. (2013) identified clear evidence that groups of Oldowan hominins acquired and processed numerous small ungulates and at least occasional access to large ungulates. Their data spans many millennia and provides clear archaeological evidence of '*persistent carnivory'* (Ferraro et al. 2013: e62174) which is missing from earlier East African sites (e.g. Dikika [McPherron et al. 2010] and Gona [Domingue-Rodrigo et al. 2005]) which preserve evidence of a specific hominin butchery act (and thus not necessarily persistent carnivory).

However it is important to stress again that it is not the direct foraging benefits of Wildfire Package exploitation that lies at the heart of FAF, although these play an important role in the overall adaptive selective pay-off generated. At the heart of FAF lies the proposition that mental benefits in terms of stress and fear reduction and reductions in investments in vigilance proved advantageous to ancient hominins through the creation of adaptively highly significant adaptive-selective payoffs. FAF proposes that the adoption of a combination of strategies deployed within both physical and mental landscapes could have enabled hominins to successfully preferentially exploit Wildfire Package affordances while conforming to all three of the Criteria for accepting the viability of an early fire theory prescribed in this study.

In addition to foraging benefits and subsequent positive impacts on energy budgets FAF predicts that intelligent utilisation of the Wildfire Package by ancient hominins would generate adaptive pay-offs and strong selective forces by providing significant biological fitness benefits through opportunities to reduce investments in anti-predation strategies, risk effects and vigilance against conspecific attack. The results of this would be numerous including potentially:

i) **Reduced levels of predation**

ii) **Significantly increased social time**

iii) **Significantly increased opportunities for parental investment**

iv) **Significantly increased dietary quality**

v) **Significantly less stressful fearful lives**

vi) **Numerous opportunities to experiment with new highly beneficial strategies** (e.g. the smoke-assisted obtaining of honey)

As LOF adaptations are here suggested to have been developed and deployed by *Homo* antecedents they are suggested to have provided some of the required adaptive selective pressures that drove the significant niche change that occurred during the transition into *Homo*, helping to explain many previously cited behavioural and morphological changes that accompanied this transition (e.g. increased range and group size). FAF is not proposed to ‘take advantage of cognitive restructuring and re-organisation’ but in fact proposes that the earliest hominin fire relationships were an active driver of ‘cognitive restructuring and re-organisation’ generating significant adaptive pay-offs; as such FAF can help to explain both the emergence of *Homo* as Mode 1 deliberate opportunistic fire-users and the nature of some inherited neural architecture that underpins modern human fire relationships (tested for in this study). FAF proposes that ancient hominins significantly gained from constructing beneficial ‘fire-related landscapes of fear’ that became an integral part of their wider niche; this study further proposes that relics of this ancient behavioural adaptation and relationship with fire are still visible within the psychology of modern humans; an idea tested in Chapters 5 and 6.

In modern humans, the ability to envisage, simulate and predict future scenarios is highly developed which allows the modification of behaviour to prepare for, escape from, or even completely avoid possible future dangers (Suddendorf and Corballis 2007, Mobbs et al. 2015); this is a form of intentional niche construction. FAF specifically proposes that aspects of this ability are ancient and predate the emergence of *Homo*. FAF further proposes that it was the use of information generated from associated learning that enabled fire-based LOF benefits to be identified and achieved. In effect a combination of prediction and prevention strategies are proposed that enabled intelligent hominins to exploit Wildfire Package affordances to benefit from minimised future interactions with risks thus decreasing investments in vigilance and/or increasing energetic (e.g. decreased GUDs) or social benefits.

Parts of the FAF hypothesis are supported by the conclusions of Mobbs et al. (2015) who proposed that two ways that humans are cognitively enhanced is by an imagination system capable of sophisticated simulations of future threat encounters and by the ability to reduce threats by niche construction; FAF requires these to be ancient hominin traits. FAF proposes that hominin fire-use is a key construct of the *Homo* niche and helps to explain the nature of modern human relationships with fire. Other proposed key constructs of the *Homo* niche that align with the FAF hypothesis include (relative to *Homo* antecedents and other apes): larger range sizes, improved dietary quality, increasingly complex social relationships and structures, increased cognitive capacity, increased levels of parental investment, higher levels of behavioural plasticity, high eurytopy, and a high degree of awareness of ecosystems, environments and environmental factors.

Main Research Question proposed by the Fear and Flames Hypothesis

Could adaptive selective pay-offs created by adaptations within ancient hominin landscapes of fear provide a robust driver for the initial uptake of hominin fire-use?

Theoretical foundations

In primate society trade-offs exist which exchange resources for safety; strategies will try to optimise both safety and foraging returns (Cowlishaw 1997). In non-hominin primate society habitat type affects behaviour and levels of fear and stress (Cowlishaw 1997). Primates (e.g. *Papio. Sp*) have been observed to shift from riskier to safer areas to reduce their predation risk (Cowlishaw 1997, Herzog et al. 2014); this normally results in a safer environment with a poorer quality of diet. Accordingly if a strategy resulted in inhabiting a safer environment with an equal quality of diet then selective advantages would accrue. Extrapolating this still further, even greater advantages could be expected to accrue (and stronger adaptive selective pressures and pay-offs) if a strategy resulted in inhabiting a safer environment which enabled an improved quality of diet. FAF does not categorically state that exploitation of Wildfire Package affordances results in this scenario, but the potential is highlighted as a plausible outcome (with attendant significant adaptive selective forces and pay-offs).

While at the height of conflagration (and for a length of time afterwards in diminishing quantities) fire has its own risks which impacts upon the thinking and actions of higher trophic levels, changing behaviour and background levels of predation risk (Burton 2009)**.** While it is obvious that wildfire changes the nature and abundance of resources perhaps it is less obvious that it also changes the behaviour of organisms inhabiting higher trophic levels, predators included. Opportunities for Plio-Pleistocene hominins to benefit from LOF impacts would be present in both the LOF of hominins as well as the LOFs of other species (prey and predator). Wildfire changes the behaviour of other members of the ecosystem, e.g. predators, browsers, grazers and scavengers, these behavioural changes are due to wildfires impacts on both the physical environment (e.g. burning away of food items such as flowers) and their LOF (e.g. burning away of refuge habitat). Wildfire burnt environments (part of the Wildfire

Package) provide a number of affordances for intelligent foragers that allow reductions to vigilance investments (Herzog et al. 2014). Optimal foraging theory (see Chapter 2) predicts that a forager will select optimal level of vigilance to balance threat detection with foraging returns; within this theoretical framework FAF predicts that, for many reasons, vigilance investments can be reduced when a group of hominins exploits a wildfire burnt environment.

Optimal foraging theory explains foraging decisions within 'black-box models', but how does that really relate to real-life decision-making processes? Is decision making purely related to foraging returns? In the real world organisms cannot precisely optimise fitness because they must estimate factors such as predator and food density (Abrams 1984). Wildfire obviously and visibly changes many attributes of the physical landscape, but it also impacts on animal's mental landscapes. It has long been recognised that some sort of trade-off exists between vigilance level and foraging behaviour (e.g. Abrams 1984, Lima et al. 1985) as animals have to weigh the risk of predation with a need to satisfy their metabolic needs which can be in direct competition (Kuijper et al. 2015); resource scarcity can alter the dynamics of this trade-off (Sih et al. 1988). Additionally for some foragers risk from predators need not necessarily be directly related to predator density but more to the habitat-related behaviour of the predator (Boinski et al. 2003). Large mammals have previously been identified as being able to detect differences in predator and resource density (Abrams 1984) and to utilise this information to make informed decisions (Kuijper et al. 2015); this behaviour falls under the banner of 'survival intelligence', defined by Mobbs et al. (2015: P2) as '*an organism's ability to master its environment by minimising local threats and adapting to novel threats in changing ecologies*'. LOF optimisation would be one way to increase survival intelligence.

This study proposes that if the presence or effects of wildfire on the landscape altered the habitat-related behaviour of potential hominin predators then this would have provided opportunities for hominin LOF optimisation that may deliver significant adaptive pay-offs. In support of this idea Verdolin (2006) specifically pointed out that in the absence of direct information regarding the location of predators then assessing predation risk via habitat structure would potentially be a reliable primate strategy. While researchers will never be fully cognisant of the form of Plio-Pleistocene hominin anti-predation strategies (including how, and with what information, risk assessments were made) FAF proposes that knowledge about habitat structure and associations between potential risk-factors and habitat would have been at the core of many strategies and decision making processes.

FAF is firmly built upon LOF theory but it should be clear that while the focus is on the LOF benefits of hominin association with the Wildfire Package, FAF is not entirely dependent on LOF benefits to justify itself as a plausible theory for the initial onset of hominin fire-use. FAF also incorporates benefits discussed within the Optimal Fire Foraging Hypothesis which are added to LOF benefits to create an overall package of benefits. The Optimal Fire Foraging Hypothesis failed to demonstrate sufficient adaptive significance due to uncertainties about the amount of resources generated by a wildfire and also the availability of hominins to harvest these resources due to competition from other foragers. **The same weakness could potentially be ascribed to FAF if only the mental benefits are taken into consideration.** However when the mental (LOF) benefits are taken into account alongside the foraging benefits then it is proposed here an adaptive selective pay-off of sufficient scale is generated. FAF therefore suggests a complex package of benefits were obtainable through Wildfire Package exploitation for ancient hominins who chose to associate with wildfire.

Fear and Flames – Key constructs

The FAF hypothesis has a number of key constructs:

i. Landscapes of Fear are real, and accord with accepted evolutionary theory (Brown et al. 2004, Laundre et al. 2010).

ii. Any behaviour change that increases reproductive rate, survivorship or both is under selection of maximum intensity (Lovejoy 1981).

iii. Natural selection increases fitness by optimising survival relevant behaviours within a given species' environment (Mobbs et al. 2015).

iv. Different habitat types have different predation risks and may require different anti-predation strategies and levels of vigilance (Hernandez and Laundre 2005).

v. The competing demands of nutrient acquisition, risk minimisation and predator avoidance are balanceable by the strategic use of habitats (Cowlishaw 1997).

vi. Foragers' perception of predation risk strongly affects patterns of resource use (Laundre et al. 2001, Brown et al. 1999).

vii. The use of space by large carnivores creates areas that are perceived as high or low risk by prey (Kuijper et al. 2015).

viii. A crucial component of hominin neural architecture is the ability to continually update and modify responses to stimuli through associative learning (Mobbs et al. 2015).

ix. Resources can be exchanged for safety; strategies will try to optimise both safety and other needs (e.g. energy budgets, nutritional requirements and social time).

x. How organisms use landscapes and environments alters fear levels and impacts on foraging strategies and evolutionary pathways (Brown and Kotler 2004).

xi. Strategies that minimise investments in vigilance without increasing risk can be modelled as providing significant adaptive selective pay-offs.

xii. Wildfire changes the nature of the landscape, resource distributions and the behaviour of every trophic level and all parts of the ecosystem and food web.

xiii. Significant changes in social structures, foraging strategies and technological toolkits between *Homo* and antecedents presuppose adaptations in landscape use.

xiv. Wildfire has many affordances; therefore the possibility for hominin fire-use being exaptive is high.

xv. A number of different benefits (both physical and mental) come together to form a complex (spatially and temporally) variable package.

xvi. Landscape heterogeneity shapes large-scale predation patterns of both coursing (Kauffman et al. 2007) and ambush predators (Hopcraft et al. 2005).

xvii. In modern humans high security is associated with open areas with long view distances (Sreetheran and van den Bosch 2014).

xviii. Human behavioural repertoire is supported by a neurobiological system with a powerful set of intelligent survival mechanisms, promoting adaptation to changing ecologies and efficient navigation of natural dangers (Mobbs et al. 2015).

xix. Observations made on extant omnivorous savanah dwelling primates have observed the utilisation of wildfire burnt environments to reduce investments in vigilance (Jaffe and Isbell 2009, Herzog et al. 2014).

xx. Ecology underlies human cognition and the development of culture

Vigilance reduction affordances of Wildfire Burnt Environments

Researchers in the field of Environmental Psychology (e.g. Balling and Falk 1982, Kaplan 1987, Kaplan and Kaplan 1989, Joye and Van Den berg 2011) have identified in a number of studies that people are more comfortable and relaxed in an open environment. Studies that deploy methodologies whereby participants are asked to rate and rank a number of different images have consistently observed open environments to be most highly favoured (e.g. Balling and Falk 1982, Han 2007, Hinds and Sparks 2011). Han (2007) observed that in his study looking at the environmental preferences between six different biomes (desert, tundra, grassland, coniferous forest, deciduous forest and tropical) the slides which were most preferred from each individual biome (each individual biome was represented by eight slides) had a much more open field of view than the lowest preferred slide from each individual biome (Han 2007). Interestingly participants in this study also significantly preferred slides with a high degree of landscape complexity (Han 2007) which links well with the acknowledgment that mosaic environments were important in our evolutionary history.

The landscape preferences of modern populations of *Homo* are not one-dimensional or only driven by ‘one kind of evolutionary experience’ but a considerable body of research into environmental preferences does suggest that fundamental likes and dislikes of aspects of our physical environment exist which are identifiable as evolutionary adaptations. Environmental preference has been suggested (e.g. Kaplan 1987, Han 2007) to signal whether a habitat or environment can support occupation or successful foraging (Han 2007). Acknowledging an innate preference for open habitats has implications on how researchers would view the initial utilisation of wildfire burnt environments by hominins.

Wildfire burnt environments are observed to provide a significantly clearer field of view than the same environment un-burnt, irrespective of the season or time of year. As was personally observed while undertaking research at Florisbad and Soetdoring wildfires and bushfires burn away a very high proportion of grasses, sedges and non-woody plant material (‘islands’ of un-burnt flora do seem to survive, seemingly at the whim of the complex physical and biogeochemical factors that determine the course and nature of any fire event); a recently burnt environment affords a much clearer field of view than the same location un-burnt. This can then be placed into a simple thought exercise: If the amount of investment in risk effects is proportional (or directly related) to the quality of the field of view then required vigilance investments may be considerably less than for the same habitat un-burnt. There are of course also potential negative impacts of a clear field of view. There may be occasions, e.g. when an individual is away from the group, is very young or infirm, when an open field of view would not be welcome; a clear field of view is only beneficial if all requirements are met.

Vigilance reduction affordances caused by the presence of wildfire on the landscape can relate to a number of different factors including: i) less predators in the area leading to an increased feeling of safety and an enhanced desire to be in that habitat; and, ii) a clearer field of view requiring reduced investments in vigilance. By definition all members of *Homo* share a similar body plan; this includes a sensory dependence on vision (Sinclair et al. 2003). An analysis of *Homo* morphology shows how crucial eyesight and vision is for predator awareness and avoidance (Sinclair et al. 2003). The identification of a close threat stimuli causes greater levels of anxiety/fear to manifest thus generating a stronger system-wide response than if the threat was far away (Mobbs et al. 2015). Within FAF reduced vigilance investments related to a clearer field of view can occur through many different processes, including: i) an overall reduced number of vigilance scans per unit time; ii) the reduced time taken by each vigilance scan due to the more open nature of a wildfire burnt environment; iii) reduced stress/anxiety/fear generated by identifying the threat earlier or from a greater distance. However risk assessment and analysis requires more than simply ‘paying attention’ (i.e. vigilance); the entire cognitive system is mobilised, including perception, attention, and memory (Mobbs et al. 2015).

FAF theory is backed up by field observations by primate ethologists who, in independent studies, have observed omnivorous primates preferentially travelling in wildfire burnt environments (Jaffe and Isbell 2009, Herzog et al. 2014). Herzog et al. 2014 speculate that this behaviour is attributable to adaptive selective pay-offs created from a combination of lesser travel costs due to reduced vegetation cover and reduced investments in vigilance due to greater visibility (predators are identifiable at increased distances and have fewer places to hide). Reduced vigilance investments come in the form of both fewer and shorter vigilance events (Herzog et al. 2014) as clearer fields of view are more quickly scanned; additionally the increased distance from areas of concealment requires fewer repetitions.

This clear field of view needs to be married with other variables such as the amount of predation risk a species is under, its level of survival intelligence and speed of population growth. For example other terrestrial bipeds such as *Papio cynocephalus ursinus* may exhibit distinctly different behaviours to what in this study are assumed for ancient hominins (Cowlishaw 1996). However the foraging rewards of this population were under ‘continuous predation risk’ from both *Panthera pardus* and *Panthera leo* (Cowlishaw 1996: 667) which is different to the predation pressure assumed in this study for ancient hominins. It is also assumed in this study that the cognitive capacity and complexity of ancient hominins is higher that extant populations of baboons. Just like with extant great apes such as chimpanzees, a lot can be gained from studying extant terrestrial bipeds; however it does need to be clearly stated that they are not direct analogues of ancient hominin behaviour, and therefore should not be used to either support or find fault with FAF theory.

The impacts and/or benefits of a ‘clear field of view’ for hominins should be judged by consideration not only of changes to physical environment (e.g. proposed reduced risks from ambush predation) but also other species mental landscapes. LOF impacts that may prove beneficial to hominins would be present in the LOFs of other prey, and predator species; recognising these and adapting accordingly can provide significant adaptive selective pay-offs to hominins. Wildfire changes the behaviour of other members of the ecosystem (Green et al. 2015 *Passim*), e.g. predators, browsers, grazers and scavengers, these behavioural changes are due to wildfires impacts on both the physical environment (e.g. burning away of food items such as flowers) and their LOF (e.g. burning away of refuge habitat or habitat used to ambush prey from).

Wildfire created ‘clear fields of view’ can provide benefits other than just ‘*general vigilance reductions*’. It is proposed here that ‘open, or clearer fields of view’ would be preferable to early members of *Homo* (and recent antecedents) foraging on the landscape. It is further proposed that clearer fields of view may allow complex, tool-assisted foraging tasks (e.g. termite fishing) to be undertaken more safely and/or with increased foraging returns. The burning away of grasses and other flora that make up the majority of savannah undergrowth provides a number of different affordances exploitable by foraging hominins, not all of which will necessarily be available with each conflagration. During this study insufficient fieldwork ‘controlled burns’ were conducted to statistically show that foraging opportunities exist in any greater frequency post-burn than pre-burn; however the increased visibility of some foraging opportunities were highlighted to researchers.

Personal observations made at Florisbad and Soetdoring during this study showed that: i) entrances to the burrows of small mammals and other creatures were much more easy to identify post-burn rather than pre-burn (Photo C); ii) certain animals were easy to find post-burn (e.g. mice and large locusts– see Photos C and D) as they suffered mortality due to smoke/heat/flames; and, iii) animals that rely on crypsis such as tortoises are much easier to find post-burn (Photo E)[13].

The benefits of being more easily able to visually identify foraging opportunities due to the wildfire produced clearer field of view (obviously this only becomes apparent once smoke has dissipated) suggests potential biological fitness benefits for hominins are created by wildfire's impact on physical environments. For ancient hominins a clearer field of view may have helped enable foragers to attain markedly increased returns and thus improve the biological fitness of themselves, their offspring and their wider social group. Hominins who successfully exploited these, in energetic terms, high quality opportunities would have been able to improve their dietary quality by obtaining many high quality resources in a small space of time. Repeated preferential exploitation of these environments by ancient hominins would have enabled both improvements to dietary quality and a broadening of dietary breadth both of which are trends that can be deduced from morphological, osteological and dental evidence to have occurred during the Plio-Pleistocene (e.g. reduced sizes of guts and jaws).

Benefits within hominin LOFs may be sufficient to cause a revaluation of the foraging decisions made by hominins at both the individual and group level. This may then render certain foraging strategies which are 'not sufficiently successful when coupled with high

[13] despite exhaustive pre-ignition searches for cryptic and hidden animals at Florisbad, during the first burn a large tortoise was badly singed and was immobile for forty five minutes (after being liberally sprayed with water), before wandering off into the scrub after which it was sited again eleven days later feeding happily; thus providing high quality observational evidence of wildfire adaptation

Photo C: A rodent killed by heat and/or smoke at Florisbad during fieldwork in 2012 (Photo by Adam Caris)

Photo D: A large locust killed by heat and/or smoke at Florisbad during 2012 fieldwork (Photo by Adam Caris)

Photo E: A tortoise seeking refuge in a termite nest immediately after a wildfire at Soetdoring Nature reserve in 2012 (Photo by Adam Caris)

investments in risk effects' to be profitably deployed. Highly time and energy intensive foraging strategies, such as termite fishing, may actually be safer and, from an energetics perspective, a more attractive proposition when a clear field of view is attainable. It may even be that reduced investments in vigilance make previously unrewarding foraging rewarding (discussed in more depth later in this chapter).

Due to so many 'known unknowns' it is difficult to specifically quantify how much of an impact, if any, physical affordances of wildfire on the landscape would have made to the foraging budgets and decisions of ancient hominins. What appears clear is that, looking at this subject in a purely physical sense, there are undoubtedly opportunities available for foraging hominins when in and around a wildfire to broaden their diet and improve dietary quality. Perhaps though, when combined with benefits within hominin landscapes of fear, physical factors (particularly the clear field of view caused by combustion of energetically and nutritionally low quality undergrowth) can be seen as making an important contribution.

Delayed fire affordances

As well as ‘clearer more open fields of view’, the FAF hypothesis highlights a number of exploitable delayed fire affordances that the Wildfire Package may contain. These include:

i. Reduced investments in travel by using a wildfire burnt environment as a travel corridor
ii. The use of fire as it persists in the form of embers and ‘root-ball’ fires. This can be in the form of fire (e.g. for cooking or warmth at night) or smoke to pacify and disorient prey or for activities such as honey collecting (Wrangham 2011)
iii. Safer more highly productive insect foraging activities due to reduced investments in vigilance (as long as only ambush predation is perceived as a significant threat)
iv. Opportunities to significantly increase investments in social time due to higher dietary quality and reduced resource acquisition times
v. Increased safety for juveniles to play due to reduced risk from predators and conspecifics
vi. Access to high quality weaning foods (e.g. insects or new shoots after rain)
vii. Highly seasonal fires provide resources in times of shortages – opportunities provided by the Wildfire Package can be considered as providing important fall-back foods
viii. The resetting of plant successions creating higher patch biodiversity and more healthy ecosystems of particular attraction to omnivores.

Fires ability to reset plant successions enables higher patch biodiversity benefiting broad dieted omnivores (Overbeck et al. 2005, Pyke et al. 2010). Herbivores (grazers and browsers) can also benefit from exploitation of Wildfire Package affordances due to greater foraging efficiency and higher nutrients concentration in post-fire regrowth (Green et al. 2015); observed significant wildlife responses to fire can last for months (Green et al. 2015). Wildfire clears nutrient-deficient biomass (Van de Vijver et al. 1999), and after precipitation, can enhance primary productivity and herbivore foraging opportunities (Van de Vijver et al. 1999). New vegetative growth after fire is preferred by some herbivores, and may temporarily alter regional species abundance (Green et al. 2015 *Passim*). Although many wildlife species use burned areas at some point as vegetation re-establishes, different strategies can be seen to exist (de Ronde et al. 2004); Green et al. (2015:236) categorised these strategies as accessing immediate post-fire conditions (<30 days post-burn), exploiting post-fire re-growth of vegetation (30–365 days post-burn) and using burned habitat after considerable re-growth has occurred (>365 days post-burn).If prey is more common and more readily accessible in burnt areas than in unburned areas it suggests that burned areas should attract carnivores (as per Eby et al. 2013 and Green et al. 2015). However reduced vegetation cover may in fact decrease the capture success of ambush-style hunters that require adequate cover to capture prey, and thus repel predators (Eby et al. 2013). Green et al. (2015) conducted some quite detailed research in this topic but found that while prescribed burning appeared to increase the local populations of both small and large carnivores, they were cautious with their results. No carnivores were observed on test sites prior to burning and therefore Green et al. (2015:241) noted that it is plausible that removal of tall grass by burning might have simply increased carnivore detection probabilities.

Herbivore and carnivore responses to the Wildfire Package are clearly influenced by complex biotic and abiotic interactions and trade-offs (Sensenig et al. 2010). While inward migration of browsers and grazers ***may*** create behavioural changes amongst large predators, thus probably raising local risk levels, insufficient knowledge about Plio-Pleistocene hominin anti-predation strategies exists to state whether this increased level of risk would be enough to stimulate avoidance of wildfire burnt environments or not. It is not beyond the realms of possibility that increased herbivore density was in itself an attractant for ancient hominins (e.g. in terms of increased opportunities for hunting and scavenging). It seems clear though that if ungulate herds can effectively exploit Wildfire Package affordances then ancient hominins with their greater cognitive complexity and greater range of behavioural adaptations would have been able to exploit the same resources if they chose.

Fear and Flames – Summary

To summarise FAF in one sentence would be to say: A deliberate hominin association with fire was initiated, driven and stabilised by adaptations aimed at maximising benefits and adaptive pay-offs available through Landscape of Fear optimisation enabled by preferential exploitation of Wildfire Package affordances; this led to a combination of changes to hominin foraging and social strategies that facilitated reductions to required levels of investment in vigilance and other anti-predation strategies. FAF fits with evolutionary theory, is plausible from the perspective of a non-fire-using hominin and by following the lines of reasoning described here does not directly result in obligate fire. Therefore FAF fits the three plausibility criteria for early fire interaction hypotheses laid out in Chapter 3. FAF prepares the hominin brain for obligate fire behaviour but does not result in it.

As well as the specific benefits laid out in this chapter the general importance of leading less fearful lives cannot be underestimated; this reduction in overall fearfulness is here argued to have played a key role in the shift in trophic level hypothesised for *Homo* relative to antecedents. By placing FAF very firmly amidst the realm of 'early fire' theories, and stating specifically that the earliest parts of FAF predate, or at the latest, are synchronous with the emergence of *Homo* this places the advent of fire-use as a significant causal factor in the emergence of increased levels of hominin co-operation and sociality and a driving force for the adaptations laid out in the Social Brain theory (e.g. Dunbar 2009, Dunbar et al. 2011, Gowlett et al. 2012, Dunbar et al. 2014). If valid, FAF would thus pave the way for the numerous societal and cognitive changes required by obligate fire-use laid out in detail by Wrangham and colleagues (e.g. Wrangham 2009) and Twomey (2011and 2013).

Based on the affordances and opportunities inherent within the Wildfire Package a number of specific hypotheses can be formulated which would help explain the onset and stabilisation of the very earliest initial relationship (Mode 1 fire-use) with fire, and act as adaptive selective forces for an ever closer relationship with fire. None are specifically preferred or cited as more likely than others. A range is presented to show the flexibility and the range of possible outcomes that FAF reasoning can engender.

1) Interactions with the Wildfire Package provided opportunities for increasingly terrestrial hominins to manage the increased predation pressures presumed to be part of life in ‘refuge-scarce’ terrestrial environments.
2) Interactions with the Wildfire Package provided opportunities for reduced investments in vigilance by Plio-Pleistocene hominins without reducing dietary quality or increasing risks such as predation.
3) Reduced GUDs and reduced investments in vigilance coupled with the removal of low grade resources may have resulted in improved dietquality for Plio-Pleistocene hominins combined with a reduction in predator and/or conspecific risk.
4) Interactions with the ‘Wildfire Package’ led to significant land-use changes that enabled increased parental investments by Plio-Pleistocene hominins in addition to foraging and Landscape of Fear benefits.

This then leads to two major questions that are central to the testing of the FAF hypothesis and are addressed in this study:

1) Would behavioural relics persist within the precautionary psychology of extant human populations that would illuminate vestiges of LOF adaptations and benefits? (This question is approached in detail and tested in chapters 5 and 6)

2) Which specific parts of a hominin community or group would likely benefit from Landscape of Fear affordances provided by the Wildfire Package? (i.e. would a specific demographic [e.g. age group or gender] be preferentially attracted to the Wildfire Package?). (Approached in Chapter 7)

Testing aspects of the FAF Hypothesis using modern humans

FAF proposes that ancient hominin exploitation of Wildfire Package affordances enabled reductions to stress and fear levels resulting in potentially significantly reduced investments in vigilance. This occurs without significant trade-offs (i.e. a reduction in dietary quality) that would reduce the value of accruable benefits. As a result of the generation of a strong selective force FAF predicts that if the very earliest, most simple, deliberate opportunistic hominin fire-use is synchronous with or predates *Homo*, this would place a psychological attraction to fire deep within the structures of the *Homo* psyche. The theoretical stance that underpins this dissertation is that fire is so fundamental to *Homo* that responses will be driven by a relationship so imbedded within neurological architecture that responses are driven by hardwired attributes moderated by cultural experience. Therefore aspects of ancient fire relationships should be identifiable within the thinking and attitudes of modern people.

Therefore to test the FAF hypothesis direct observation and quantification of exactly how modern populations internally frame fire is required. Knowing how people now think about and frame fire can perhaps shed light on remnants of the earliest cognitive relationships with fire. To provide sound investigatory foundations prior to assessing the nature of ancient hominin mental relationships with fire, modern ones should be clearly observed and documented. This study uses data from accessible modern populations to generate and support behavioural models of inaccessible ancient populations; accordingly postulates and null hypotheses were generated and tested. Here a questionnaire-based methodology was designed with the aim of generating data of sufficient quality to be able to attempt to make inferences about the evolutionary history of the genus *Homo* and fire.

Equipped with knowledge and data from modern landscapes of fear research investigation can then take place looking for any evolutionary explanation for observed relationships. Other investigators in this field appear to also be contemplating the multitude of benefits anthropological research in this area can bring. At the Royal Society meeting, 'The Interaction of Fire and Mankind', held in London in September 2015 Keynote speaker Professor Andrew Scott noted (in his speech and within private conversations) that almost nothing is known about human attitudes towards fire, observing that very little work has been conducted in this area, before highlighting the specific need for research into how people perceive, view and mentally interact with fire. This meeting took place after the UK cohort had been recruited for this study.

Hypothesised ancestral fire relationships

It appears necessary here to explicitly state the nature of hypothesised ancestral fire relationships to then test how they match up with modern attitudes to fire. It is not neccessarily the very earliest relationships that will be discernable but the relationships that have been the most evolutionarily significant; i.e. the time when fire-use was most adaptively significant. FAF proposes that this was during the transition from *Homo* antecedents to early *Homo*. If the FAF pathway is correct then it was the psychological attraction to fire through LOF benefits and LOF adaptations that was evolutionarily important. If fire was very important to hominins before it is archaeologically visible (and before out-of-Africa migrations) then it is proposed here that it would have been very broadly positively regarded by hominins who would have been very atttrcated to it (perhaps even from a great distance) and its multiple potential affordances.

Therefore it is assumed that the ancient ancestral condition included traits such as: i) A very positive attitude to fire (i.e a greater recognition and preference for the positive aspects of fire over the negative aspects of fire; ii) a clear recognition of the usefulness of fire; and iii) a strong attraction to fire and a strong desire to interact with fire and the affordances of the wildfire package. FAF proposes that in modern populations these will not only be culturally mediated but will also be present within underlying neural architecture. Before the research is introduced a very brief review of some aspects of known hunter-gatherer landscape fire behaviour (here termed off-site fire use) is given (Scherjon et al. 2015 have recently provided a full review). Before this information is provided it should once again be stated that for many reasons no hunter-gatherer group can act as a direct analogue of ancient hominins not least because of the access they have to a range of relatively modern technologies. A brief review is provided here to illustrate the breadth of uses that hominins can conceive and deploy to benefit from the diverse impacts of fire on the landscape, and the continuity of this kind of behaviour from that which FAF proposes was the earliest hominin fire interactions.

As was mentioned in Chapter 2 (P80) linking this study to any specific species or site would expose the entire hypothesis to attack, because it would have to be defened on those specific terms - with the ‘possibility of the baby being thrown out with the bathwater’. However this does not preclude an analysis of modern potentially analogous habitats or environment such as the ‘Zambezian’; a very seasonal and very fire-adapted woodland savannah floral zone that is currently one of the largest biomes in Africa. Perhaps of great interest to this study, some Zambezian habitats (e.g. mopane woodland) offer trees high in calcium oxalates which results in them potentially burning for months thus supplying a relatively long-lived source of fire. Zambezian habitats are characteristically interspersed with edaphic grassland and semi-aquatic vegetation as well as areas of evergreen groundwater forest, thus at a very simple level mimicking the mosaic habitats identified to have been inhabited (and perhaps preferred) by ancient hominins (White et al. 2015).

While analysis of these habitats may provide useful broad insights they would still be limited by the same issues previously highlighted. Namely that modern distributions of fauna (including ungulates and carnivores) are very different to Plio-Pleistocene distributions and so cannot be used as reliable analogues. Additionally, while Zambezian ecotypes have not necessarily evolved in the past 2.5 Ma (and there is no evidence to say that they have), the fire regimes present now are anthropologically moderated (due to landscape management practices and multiple kinds of anthropogenic ignition sources) and are presumed to be, in nearly all (if not all) cases, significantly different from their Plio-Pleistocene counterparts. While an analysis of site-specific studies may be presumed to add some greater context to the arguments put forward in the FAF hypothesis (notwithstanding that FAF is purposely a general theory not linked to a specific site, hominin species or date), Dominguez-Rodrigo and

Musiba (2010) laid out a convincing case as to why paleoecological reconstructions of early paleontological sites canot yet be categorised as trustworthy (and see Chapter 2).

The impact of modern hunter gatherer off-site fire use on the direction of this study

Scherjon et al. (2015) presented a systematic global inventory of extant hunter-gatherer burning practices; including the reasons for burning and the environmental setting of firing activities. While the specific reasons for burning varied widely, many hunter-gatherer firing practices created more highly mosaic environments than would have occurred naturally (Scherjon et al. 2015). Scherjon et al. (2015: 299) specifically point out that '*the historical visibility of hunter-gatherer burning activities contrasts with the relative invisibility of such practices in the contemporary archaeological record, highlighting the difficulty of analysing past uses of fire*'. They then go on to explicitly suggest that '*diverse off-site fire use is as old as the regular use of fire*' Scherjon et al. (2015: 299). One seemingly very important way that many hunter-gatherers build their ecological niches is through interactions between fire and landscapes. While this realisation does not support the FAF hypothesis per se, it is here proposed to be a visual example of the kind of relationship that would have ensued if fire had a very ancient history of being used by hominins for niche constructive purposes; either physical or mental. Even though very ancient hominin repetitive firing practices aimed at short-term benefits may have resulted in longer-term consequences for the structure and distribution of landscapes (as per Scherjon et al. 2015), which can conceivably even be on a scale that would be visible in the geological record, identifying (and robustly defending) them will be a very difficult prospect that was not attempted in this study.

Off-site fire use for niche constructive purposes can include strategies such as burning for hunting or for improvement and increased predictability of resources, burning for ease of movement across a terrain and communication as in the case of the Martu of western Australia (Bird et al. 2005, 2008, 2013); all of which are here assessed as potentially having significant adaptive selective fitness benefits, and all of which are would have been feasible strategies for ancient hominins with some semblance of fire control. The use of these strategies would be dependent on cognitive capacity; many of which require the cognitive abilities identified by Twomey (2011, 2013) including the ability for future planning. As with the timing of naturally ignited wildfire, off-site burning by hunter-gatherers can be very much a seasonal affair (Scherjon et al. 2015); often the timing is very much dependent upon the specific effect required.

Scherjon et al. (2015: 311) conducted a relatively comprehensive cross-cultural review of the literature (including the eHRAF database) and found that 'off-site fire use by hunter-gatherers and other people practicing traditional subsistence strategies is omnipresent, carried out by males, females, and children and by individuals and groups of all sizes'. Hunter-gatherers were observed to use fire as a tool off-site for a range of activities, largely irrespective of gender and age. Where complex modern technologies were lacking off-site burning was found to be '*particularly beneficial*' leading Scherjon et al. (2015: 311) to conclude that it was more important in the past than now. What is perhaps of most interest to this study is the fact that the work of Scherjon et al. (2015) clearly highlights the range of short and long-term benefits for off-site burning; which fits neatly with the FAF hypothesis and the impact of fire on the landscape creating multiple potential adaptive selective pay-offs for both modern and ancient hominins.

The amount of environmental niche construction was found to perhaps have reached a peak in some Australasian environments where, in the absence of historical aboriginal practices, recent dramatic afforestation attests to the scale of these previous practices (Scherjon et al. 2015 passim). As was discussed previously most archaeological research into ancient fire has been focussed on the search for, or identification, of hearths. The search for, or identification, of off-site burning practices in the deep past would suffer from the same kind of difficulty and issues that were previously reviewed in depth for the identification of the earliest hominin fire interactions; e.g. what would provide incontrovertible proof? And how could researchers differentiate any potential evidence from those of naturally occurring unadulterated wildfire? Despite this Roebroeks and Bakels (2015) identified evidence suggestive of off-site fire activities by Eemian Neanderthals (MIS 5e) at the site of Neumark-Nord 2, over a 2,000–3,000 years; the charcoal evidence identified and analysed appeared to cease in conjunction with all other lines of evidence giving credence to this conclusion.

As Scherjon et al. (2015:313) concluded that off-site fire use in the deep past is nearly invisible and that there was seemingly little or no off-site fire use by hunter-gatherers before the Holocene this may make the reader question that linkage: perhaps it is because it is invisible that it is assumed not to have taken place. What is now considered off-site fire use may be much more closely related to the earliest kinds of ancestral fire-use than the use of fire in hearths for cooking or for warmth. The fact that off-site fire use is very firmly focussed on landscape level changes, which is exactly what FAF proposes was the initial attraction (and adaptive selective force) for ancient hominins, is here viewed as strengthening both the broader FAF hypothesis and the decision to test it by using a cross-cultural study (including a very recently hunter-gatherer community) in this study study despite the inherent limitations of this approach.

Chapter 5 – Surveying modern human attitudes to fire

Introduction

This study identified and documented attitudes to, and relationships with, fire from cross-sections of three different populations from different socio-economic and ethnic backgrounds. Research was designed and implemented in a specific attempt to identify and illuminate some behavioural relics of ancestral relationships with fire which, if evolutionary psychology concepts are correct, would still be present within the neural circuitry of the modern human brain responsible for 'fear and risk' identification, minimisation and management. One rationale of comparing cohorts from the UK and the (Ugandan) Batwa is that participants will have lived such different lifestyles and gained so many different personal experiences (generally in life as well as specifically related to their individual fire-use) that attempts can be made to explain any identified similarities and differences within datasets.

A unique cross-cultural methodology aimed to specifically investigate whether differences within and between populations are present and to identify statistically any significant trends. Data is classed as ordinal data as this methodology generates results dependent on the subjective feelings each respondent has. Within this study only unsystematic variation exists, no deliberate manipulation of data was attempted. A broad suite of rigorous non-parametric statistical tests has been applied to raw data to attempt to draw out and identify statistically significant relationships and trends. In this chapter the nature of the cross-cultural methodology used to test the FAF hypothesis is laid out; in Chapter 6 results and analysis are presented.

It is important to state clearly that it cannot be affirmed that within this study no '*Tertium quid*' is present (a third factor that acts as a confounding variable) which may have influenced the output. Fire in modern industrial consumerist society is very well hidden and is often seen as dangerous and something to be very tightly controlled, rather than a natural process. Over the past 100 years it has effectively been built out of society (Gowlett 2016). How has that impacted on hominin psychological relationships with fire? Has it overridden deeply imbedded relics of ancestral relationships garnered during our evolutionary past? This study cannot hope to answer overarching questions such as *whether a universal attraction to fire exists?* It may be able to shed a little light in this area by quantifying the attitudes to fire of three diverse communities. There are however specific research questions and goals that this study can hope to address a little more fully:

Broad goals of this survey study

i) To identify and document how fire fits into current mental landscapes of fear and to see whether this differs between test groups.
ii) To test cross-culturally for determinates of modern fire-based Landscapes of Fear.
iii) To broaden the existing body of knowledge of human attitudes to fire and distinguish if evidence of potential ancestral behavioural relics can be identified within three modern populations, fire-related, mental landscapes.
iv) To test if potential ancestral behavioural relics are discernible in modern populations' attitudes to fire that are consistent with, and support, the Fear and Flames hypothesis (FAF).

Specific research questions of this survey study

i) How is fire perceived by the test populations? How does fire fit into the modern human landscape of fear?

ii) Do attitudinal differences exist between test groups within the 'fire-based Landscapes of Fear' created by this sample of modern people?

iii) Do the urban and rural populations sampled differ in their attitudes to fire?

iv) Do the attitudes and perceptions of fire of the hunter-gatherer group sampled differ significantly from other cohorts?

v) Do hunter-gatherer attitudes and perceptions of fire more closely resemble hypothesised ancestral relationships?

vi) Does being a parent significantly change a respondent's attitudes and perceptions of fire?

vii) Does having received an injury from fire significantly alter a respondent's attitudes and perceptions of fire?

viii) Is greater interaction with fire linked to an increased attraction or fear of fire?

ix) Can observed statistical trends be evidence of ancient behavioural relics?

Cross-cultural research into Modern LOFs – Methodology

This study uses qualitative research methods expressed by means of a short questionnaire (Appendix B) to identify participants' use of fire during their lifetime, how they feel about fire and the relative strength of those feelings. The study was conducted between December

2014 and March 2015 in the UK and in November and December 2015 in Southwest Uganda. Three cohorts (C1, C2 and C3) from distinctly different socio-economic communities were recruited and surveyed (N=661). Participants were recruited from: i) a broadly selected UK sample (N=217, termed C1); ii) very recently hunter-gatherer Ugandan Batwa communities from the Kabale and Kisoro districts of Uganda (N=225, termed C2); iii) a cohort of educated Non-Batwa African (NBA), predominantly ethnic Muchega and Mufumbira from the Kabale and Kisoro districts of Uganda (N=219, termed C3).

The study used qualitative research methods to identify: i) how people feel about fire; and ii) what tasks they have used fire for in the past. An anonymous questionnaire was designed to explore respondents' attitudes and perceptions of fire so as to be able to model how fire fits into their mental Landscapes of Fear (LOFs). The questionnaire was specifically designed to be quickly and easily self-completed by participants to encourage compliance, help assure respondents of anonymity and to facilitate the gathering of a large sample size within given time and financial constraints. The questionnaire was piloted, prior to implementation, amongst students and early career academics from the School of History, Languages and Culture at the University of Liverpool to assess ease of answering and identify any problems with completion. Feedback from the pilot study found that the questionnaire was deemed to be easy to use and understandable and was thus only slightly modified prior to deployment.

This data collection tool was specifically designed to be qualitative in nature and to provide continuous data rather than ask binary questions. Qualitative research methods were selected for this study to enable the nature and strength of feelings and attitudes to be collected and analysed. This questionnaire collected: i) data on peoples' perceptions of fire (Q1); ii) the breadth of their experience of using fire (Q2); iii) whether they had previously been burnt or not, and if so how serious the burn was (Q3); and iv) some basic demographic questions so as to try to identify any controlling factors as to why people perceived or thought about fire in a certain way (Q4-11).

Expected trends and patterns

The sample populations were selected with the intention that results from the UK cohort (C1) would be illustrative of the Western European modern industrialised fire-based Landscape of Fear (LOF) and that results from the Batwa cohort (C2) would illuminate a current African (recent) hunter-gatherer fire-based LOF. It was predicted that for most participants from the UK (C1) fire is almost completely hidden away and that daily interactions with fire are not the norm. It was predicted that due to their lifestyle every Batwa (C2) participant would experience daily fire interactions. It was predicted that some NBA participants (C3) would have a level of interaction with fire similar to C1 and that some would have a level of interaction with fire similar to C2 but that the majority of C3 participants would have a level of interaction with fire somewhere along the fire-experience spectrum between C1 and C2. It was predicted that C1 would have diverse geographical, lifestyle and cultural differences with both other cohorts, but these differences would be greater between C1 and C2 than C1 and C3. It was predicted that participants from C1 and C3 may have had attitudes to fire that were influenced by media exposure; previous personal knowledge of Ugandan Batwa living conditions and lifestyles suggested this may not be the case for C2.

It was predicted that C3 would have many lifestyle and cultural differences with C1, but share language, education and many technologies (e.g. phone and internet use, cars, electricity, access to healthcare) that participants of C2 almost totally lacked. C3 shared geographical and some cultural similarities with C2 (i.e. both from the same area and subject to the same laws and political landscape) but significant linguistical, lifestyle and cultural differences existed.

Results from the NBA cohort (C3) would expected to be useful in a number of ways, firstly to test whether any different patterns or trends visible in the data collected from the UK and the Batwa cohorts were also present in the NBA cohort; respondents from which have very different lifestyles to participants from the UK and the Batwa cohorts. A cross-cultural comparison from three cohorts (as opposed to two) should allow for common trends to be more clearly identified. Data from the NBA cohort when compared to the Batwa data would help elucidate whether a recent extremely close relationship with the natural environment results in a distinctly different fire-based LOF (and vice versa). The nature of this methodology expects that comparison between C1 and C2 would show differences between how modern societies and (recent) hunter-gatherers 'frame' and think about fire. Comparisons between C2 and C3 would do the same and would also show if different cultures and lifestyles impact on fire-based LOFs. Comparisons between C1 and C3 may also illuminate how geographical and cultural differences between communities with the same language (and to some extent technologies) can impact on fire-based LOFs.

During the design phase of this data collection exercise many different ideas and concepts were considered including having some group-specific questions. However it was decided to only collect data that could be cross-culturally compared so as not to deviate from the core objectives of the study. Additionally it was thought that extending the questionnaire would increase the number of refusals; an idea confirmed during pilot studies.

Postulates

As well as purely documenting and quantifying how fire fits into modern LOFs, a major aim of this research is to see if any inferences can be generated regarding the nature of Ancient hominin LOFs. Until very recently the Batwa were living a lifestyle that bore, of the three cohorts, the expected most similarities with ancient hominin ways of live (hunting/gathering/ foraging). However it must be noted that the Batwa have a long history of interaction with farming communities; the impacts of which are visible genetically (Perry et al. 2014) and linguistically (personally observed by researchers during data collection as part of this study); these realisations will to some extent affect their value as analogues of relic attitudes to fire. However to paraphrase Chris Stringer: researchers must use what resources they have available. A prediction at the heart of this study is that the Batwa LOF will 'reasonably accurately resemble the, very positive, proposed ancestral LOF' and that the UK cohort will have the most negative risk-averse framing of fire as UK lifestyles are most distant from ancestral lifestyles. UK participants are envisaged as having the least opportunities to reinforce positive relationships through personal experience. Following these rationales a number of postulates were formulated specific to this data collection exercise.

Postulate 1: That those people with the broadest personal experience with fire will have the most positive attitude to fire (possibly through the reinforcement of an inherited attraction expressed through the release of hormones and serotonins when interacting with fire).

Postulate 2: That the Batwa will have the most positive attitude to fire. Their fire-based LOF will, to a greater degree than the other communities' surveyed, recognise the positive attributes of fire.

Postulate 3: That the UK cohort will have the least positive attitude to fire. Their fire-based LOF will, to a greater degree than the other communities' surveyed, recognise the negative attributes of fire.

Postulate 4: That the results from the NBA cohort would be somewhere between the Batwa and the UK data; i.e. the NBA cohort would have a more positive attitude to fire than the UK population but more negative attitude to fire than the Batwa.

On a more simple level it was predicted prior to undertaking fieldwork that rural inhabitants (or people who grew up in rural areas) would have a more positive attitude to fire due to perceived greater personal interactions. Smoking is one way to obtain a frequent relationship with fire (particularly in societies where fire is mostly hidden) so smokers can be predicted to have a more positive attitude to fire than non-smokers.

Postulate 5: People who live, or have lived, in rural areas will have a more positive attitude to fire than urban residents.

Postulate 6: People who smoke will have a more positive attitude to fire than non-smokers.

Specific postulates were also proposed regarding the impact of risk-affecting variables.

Postulate 7: Despite the increased risk adversity expected around fire when a respondent has had a significant negative personal experience (being burnt) it is postulated that this will be mitigated by a natural (inherited) attraction to fire and will not be observed to significantly predict negative attitudes to fire.

Postulate 8: Despite the increased risk adversity expected when a respondent has young children it is postulated that this will be mitigated by a natural (inherited) attraction to fire and will not be observed to significantly correlate with negative attitudes to fire.

In addition to these postulates the effects of variables such as age and gender were also tested for. To address these postulates, and for the specific purpose of statistical analyses, a number of null hypotheses were constructed to be empirically tested. These null hypotheses may in practice turn out to be unrealistic views of the evidence but are required for statistical analysis.

Null hypotheses

Null hypothesis A: No statistically significant differences exist between the fire-use-history of the three cohorts.

Null hypothesis B: No statistically significant differences are visible between the fire-based LOFs of the three cohorts.

Null hypothesis C: That no statistically significant differences are visible between the fire-based LOFs of the three cohorts that can be explained by differences in fire-use behaviour or fire-use history (i.e. while variation may exist between different cohort's attitudes and mental relationships with fire these differences are not due to differences in fire-use behaviour or fire-use history or whether participants have had previous adverse interactions with fire).

Null hypothesis D: That whether a participant lives, or has lived, in a rural or urban environment has no statistically significant impact on the nature of their fire-based LOF.

Null hypothesis E: That whether a participant has (or does not have) children, has no statistically significant impact on the nature of their fire-based LOF.

Null hypothesis F: That whether a participant smokes (or has previously been a smoker) has no statistically significant impact on the nature of their fire-based LOF.

Null hypothesis G: That gender has no statistically significant impact on the nature of a person's fire-based LOF.

Null hypothesis H: That age has no statistically significant impact on the nature of a person's fire-based LOF.

Informed Consent

As part of the ethical approval granted by the University of Liverpool's HLC ethics committee, prior to undertaking the questionnaire all participants from every cohort were required to provide informed consent. The UK and the Non-Batwa African cohorts were provided with a double-sided A4 hand-out (Appendix C) and asked to tick a box at the top of the questionnaire to show informed consent; the Batwa were post-briefing twice asked verbally to consent prior to data collection commencing. All participants were informed that participation was entirely voluntary and that they could stop at any time and ask any questions they wished (UK participants recruited via a snowball methodology were provided with the relevant contact details to facilitate this data request). Those unable or unwilling to comply were thanked for their time and did not provide any data for this study.

Question 1 - Word-pairings

Question one (Q1) contained eleven word-pairs, all of which could be broadly classified as containing: i) a positive aspect or trait of fire, or a positive emotion that could be used to describe fire; and ii) a negative aspect or trait of fire, or a negative emotion that could be used to describe fire (See Appendix B). The words were specifically designed **to not be direct opposites of each other** to aid the attempt to identify and quantify each individual respondent's personal attitudes to, and ways of thinking about, fire in great detail. It was envisaged that these word-pairs, while not being exact opposites, did highly contrast with each other giving respondents very different concepts to find their own personal balance between; in effect while not being direct opposites they can be viewed as opposite ends of a spectrum. Not being direct opposites hopefully allows a personal balance between two concepts to be identified.

A Likert (Likert 1932) scale was not employed as it was deemed important not to overly constrain responses. In addition, by presenting an unusual or novel data collection methodology to respondents it was hoped that it would encourage people to think a little more deeply about their responses. Therefore a horizontal space was given to respondents where they could place their mark (a cross or a tick); no markings or other demarcation was added to aid respondents. Respondents were asked to: "Please look at each pair of words below and place a cross in the space between them to show ***how you feel about fire***. The closer your cross is to one word the more ***you feel*** that option. Placing a cross in the middle means you think both words apply equally to how you ***feel about*** fire.

The space between the two words was 120mm, which with the aid of a ruler was easily numericised into a scale of 1-120, with 1 and 120 representing the ends of the spectrum of answers and 60 being a balance between the two words being considered. It was decided to use a scale of 1-120 rather than a scale of 1-100 so that results would not be confused with percentages. Due to the 120 different potential responses to each part of Q1 it was decided that mode values would not be relevant as too many different options exist; in this report only mean and median values are provided. Within the physical questionnaire some of the word-pairings were presented with the 'negative' emotion first and some with the positive emotion first so as to make the respondents think more carefully and deeply about their responses. However during the analysis those with the negative concept first were reversed to aid analysis (and the suffix [rev] was added to the variable name so that researchers were aware of where this reversal has occurred). This reversal was particularly necessary to aid higher level statistical procedures such as Hierarchical Cluster Analysis (as it was Hierarchical Cluster Analysis results did not provide any extra resolution to trends within results and are therefore not presented in the final version of this dissertation).

For the purpose of consistency word-pairs (e.g. safescary) are presented as one continuous word rather than two words. This is because as data was entered into a dedicated database using SPSS 22, which does not allow 'spaces' to be part of 'variable' terms, word-pair terms are presented in this dissertation as they appear in SPSS generated figures (see Chapter 6); i.e. without spaces. For example, safescary is preferred to safe-scary or 'safe scary'.

ProtectiveRisky(rev)

As risk and the perception of risk are central to this study it was deemed important to start with the word risky to place into the minds of respondents exactly what researchers were looking for information about. 'Risky' was paired with 'protective' because the concept of hominins first utilising fire for protection or as a way to minimise investments in vigilance and reduce the risks of predation lie at the very heart of this study.

ExcitingDangerous

The exciting/dangerous question really lies at the heart of this study as it expresses key emotions that comprise the proposed fire-related landscape of fear. That fire is dangerous is undeniable, but it is the question of how respondents have tempered their responses by factoring in the ‘exciting’ element, and whether this is strong enough to overcome the dangerous element, that is of specific interest.

WarmingBurning

It is obvious to most people with experience of fire that fire can warm and fire can also burn. Warming can be described as a positive effect, while burning has definite negative connotations (e.g. ‘I warmed dinner’ as opposed to ‘I burned dinner’). The warming/burning question was designed to attempt to ascertain whether participants generally viewed fire positively, or negatively. As one of the questions in the study investigates whether a participant has been previously burnt this question seems particularly relevant to test if negative experiences with fire impact greatly on fire perception.

SocialViolent(rev)

Social and violent cannot really be considered as anything like direct opposites but they do suggest very different concepts and states of being; albeit it is accepted that something can be social and violent at the same time. However when it comes to thinking about fire asking respondents to think about fire as either being social or violent is asking people to think about fire in two very different contrasting ways; their personal balance between these two words may illuminate their deepest feelings about fire.

SafeScary

SafeScary was formulated as a question as it gets right to the heart of the topic approached in this study, namely where does fire fit in the modern human LOF? Does it pull people towards it, or push them away? Is it safe or is it scary? Which emotional and physical responses does it stimulate most? Of course due to the very disparate forms that fire can take fire can be both and can also shift from one state to another very quickly. Answers to this question coupled with statistically significant relationships with key demographic variables and any cross-cultural differences within the data have the potential to strongly illuminate, or point towards, potential evolutionary relationships with fire; particularly which parts of early hominin society may have been particularly interested in starting and maintaining relationships with fire. Statistically significant differences, if any, between different sections of society (e.g. urban/rural, male/female, young/old) are of particular interest.

UsefulHazardous(rev)

This question was included in this study not only for the inferences that analysis of the data can provide to researchers regarding fire based LOFs but also because it gives a real insight about people's perceptions of fire in general. Something can very easily be useful and hazardous, but it is very much where the individual balance lies that makes responses to this word-pairing very interesting.

ComfortingStressful

This word-pairing was formulated to see how fire made respondents feel about their personal proximity to fire; whether it provides comfort or raises stress levels. In essence choosing between comforting and stressful illuminates a lot about a respondent's general attitude to fire and was included in this study as a useful tool (or barometer) to test cross-cultural attitudes and how they might vary.

FriendlyFearsome

Asking respondents to choose between the opposing concepts of friendliness and fearsome gets to the heart of fire and how it fits within modern psychological landscapes of fear. When the questionnaire was being developed it was expected that responses to this word-pairing would correlate strongly with the breadth of a respondent's fire-use experience.

GiftThreat

This variable was designed to attempt to identify how people think about fire abstractly, rather than what emotional response is stimulated by fire. Respondents were asked to find their own personal balance between viewing fire as a gift or a threat. From a cross-cultural perspective it will be very interesting to compare the mean and median values and observe how, on a community level, fire is perceived. Again when the questionnaire was under development it was expected that responses to this word-pairing would correlate strongly with the breadth of a respondent's fire-use experience.

AttractingRepelling

This variable was designed to illuminate whether people thought that fire was a positive thing, ‘drawing them in’, or a negative thing, ‘pushing them away’. This cuts right to the centre of this PhD study, and the theory that psychological attraction to fire may have been the precursor to, and thus underpins, all other fire-use strategies.

CleansingDestructive

This variable was constructed to try to ascertain how respondents view the transformative nature of fire. Is it ‘positive’ in that it cleans and cleanses an environment? Or is it the ‘negative’ destructive nature of fire that dominates? Of course fire may cleanse and be destructive at the same time, but researchers want to get at the heart of how fire is perceived as transforming objects, fuel and/or landscapes. It is this transformative nature of fire and its impact on different trophic levels, ecosystems and landscapes that FAF hypothesises lies at the heart of the earliest hominin interactions with fire.

Question 2 – History of fire-use experience

In question two (Q2) (Appendix B) the following question was asked: Have you used fire (where you can see a flame) for any of the following reasons? (Please tick all that apply)

	Yes		Yes
Keeping insects away		Cleaning and cleansing	
Cooking food		Boiling water	
Keeping warm		Killing plants	
Light		Burning rubbish	
Signalling		Making things	

Q2 was attempting to quantify the breadth of a respondent's personal fire-use experience. Responses from Q1 could then be plotted against responses from Q2 to ascertain whether statistically significant relationships exist. Does the breadth of fire-use experience impact significantly on a person's fire focussed Landscape of Fear? For purely anecdotal reasons participants were also asked to state if they had ever used fire for any reason not listed. Socialising and having fun were the most popular responses to this additional data request.

On reflection this section could have been altered or expanded to gain more precise information, or to counteract the issues later encountered when trying to utilise the 'breadth of fire-use' data. One theme that could (and perhaps should) have been explored further was the separation of domestic and non-domestic fire-use, to identify the range of optional fire-uses as compared to those required by culture and personal circumstances. A small amount of qualitative data was collected in this section (with other ad hoc qualitative data collected during Batwa interviews). This data was not analysed *per se* but was instead used as anecdotes and to inform the framing of results and the wider FAF theory.

Question 3 – Burnt or not?

In Question 3 (Q3) participants were asked: Have you ever been burnt by fire? Yes / No

If yes, please place an X between the two options below to indicate how severe your worst burn was.

(The same space and scale as provided to respondents in Q1 was then provided so that respondents could self-assess the severity of their own injury on a scale of 1-120 [with 1 being least severe and 120 being the most severe]).

Responses from Q1 could then be plotted against responses from Q3 to ascertain whether statistically significant relationships exist. Does a previous negative experience with fire significantly impact on a person's fire focussed Landscape of Fear? In hominin evolutionary history relationships with fire, particularly wildfires, will have had attendant risks. Having the ability to mentally overcome any negative experiences and still benefit from all that a close relationship with fire can offer would be an advantageous trait, hence why it was considered important to collect and analyse this data.

Demographic Questions (Q 4-11)

Seven further questions were asked participants to collect some anonymous demographic information (Q 4-11). This demographic information included: i) the gender and age of the respondent; ii) whether they have produced any children, and if so, the age of the youngest child; iii) whether they grew up in a rural or urban environment, and whether they live in a rural or urban environment now; and iv) their current smoking status and their smoking history.

Information such as age, sex, whether they had children, had been a child or an adolescent in rural or urban areas, or had a history of having been burnt was collected so as to look for any trends or relationships that are influential in determining how someone feels about fire. Asking what tasks they have used fire for in the past, and whether they smoked or had previously smoked, were methods of understanding how broadly they had been exposed to fire and the nature of their experience with fire. It was hoped that responses from Q2-11 would provide sufficient statistically significant relationships to the data provided by Q1 so as to be able to make some judgments about landscape of fear differences between the three communities surveyed in this study. Inferences from this study, if considered clear enough and of sufficient quality could then be used to help construct models that could then be applied to the proposed earliest deliberate opportunistic hominin relationships with fire within hominin deep prehistory.

The Batwa Pygmies of Uganda

The Batwa[14] Pygmies are believed to be the original inhabitants of the great lakes region of Central Africa (Lewis 2000). Traditionally the forest was their home; a habitat in which they had a low impact over many thousands of years (Lewis 2000). First hand oral testimony obtained during field research highlighted the important role fire played within traditional Batwa culture, including a number of important ritualistic and practical roles; e.g. large fires for communal gatherings and safety from predators (Ssemiseru Wilbur Pers. Comm.). After incursions and deforestation from Bantu farming communities, which accelerated in the nineteenth century, the Batwa were partly integrated into wider society at the lowest levels

[14] In this dissertation the Ugandan term ‘Batwa’ (as used by Lewis 2000) is preferred to the Zambian ‘Ba Twa’ (as used by Barham 2006). Batwa can be translated as ‘people who always move’ or ‘the other’ (Barham 2006); translations which clearly highlight their lack of status in modern African society.

(Lewis 2000). Deforestation accelerated during the 20th Century leaving the Batwa inhabiting remote forest refuges; in Uganda this was the Echuya forest and the swathe of forest that blankets much of the Congo/Uganda border area. With the gazetting of a number of new National Parks in the latter part of the 20th Century the Batwa were expelled from their former forest homes without compensation (Mgahinga National park which rests right in the middle of the research area was gazetted in 1991).

This chain of events forced the Batwa into their current economic system that can be best described as ‘subsistence labouring’; effectively landless and mostly unable to access forest resources. Even their former skill as potters and makers of other ceramic products was destroyed (along with the respect these skills engendered within local populations) in the 1990’s by an influx of very cheap and locally desirable Asian (e.g. Chinese and Indonesian) plastic plates, utensils and containers. During the 20th and early part of the 21st Centuries their culture and way of life was placed under increased stress due to several severe ‘inter-‘ and ‘intra-‘state upheavals and violent conflicts which have undermined their livelihoods and culture even further (Lewis 2000) (e.g. the 1994 Rwandan genocide, and the numerous Congolese wars/conflicts); although the Ugandan Batwa were probably the least impacted of all the Batwa of the Great Lakes Region (Lewis 2000) (see Fig. 5.1 for the current full distribution and range of the Great Lakes Batwa). It was observed during data collection that for most of the visited Ugandan Batwa communities (almost) total poverty has become a reality and that their traditional ties to the forest and land are under severe pressure. Recently the situation of the Batwa has started to become slightly less bleak with the influx of a profusion of NGOs, some of who seem to actually work in collaboration with (and in the best interests of) the Batwa; something that historically has not always been the case.

Within this cross-cultural study, for a number of reasons, the Ugandan Batwa of Kisoro and Kabale districts were chosen as the 'traditional' community to study. First, being recent hunter-gatherers (many of the older people interviewed as part of this study were born in the forest) people's attitudes and perspectives are still very heavily influenced by their recent rich cultural heritage. Second, the Ugandan Batwa we visited live in small communities of between 5 and 60 adults meaning that a community can be surveyed within one day (the most individual interviews performed in a single day was thirty); communities live geographically proximal to each other making data collection relatively simple (Fig. 5.2). Most days the research team had to walk only 6-20km, although on a couple of occasions this was significantly more.

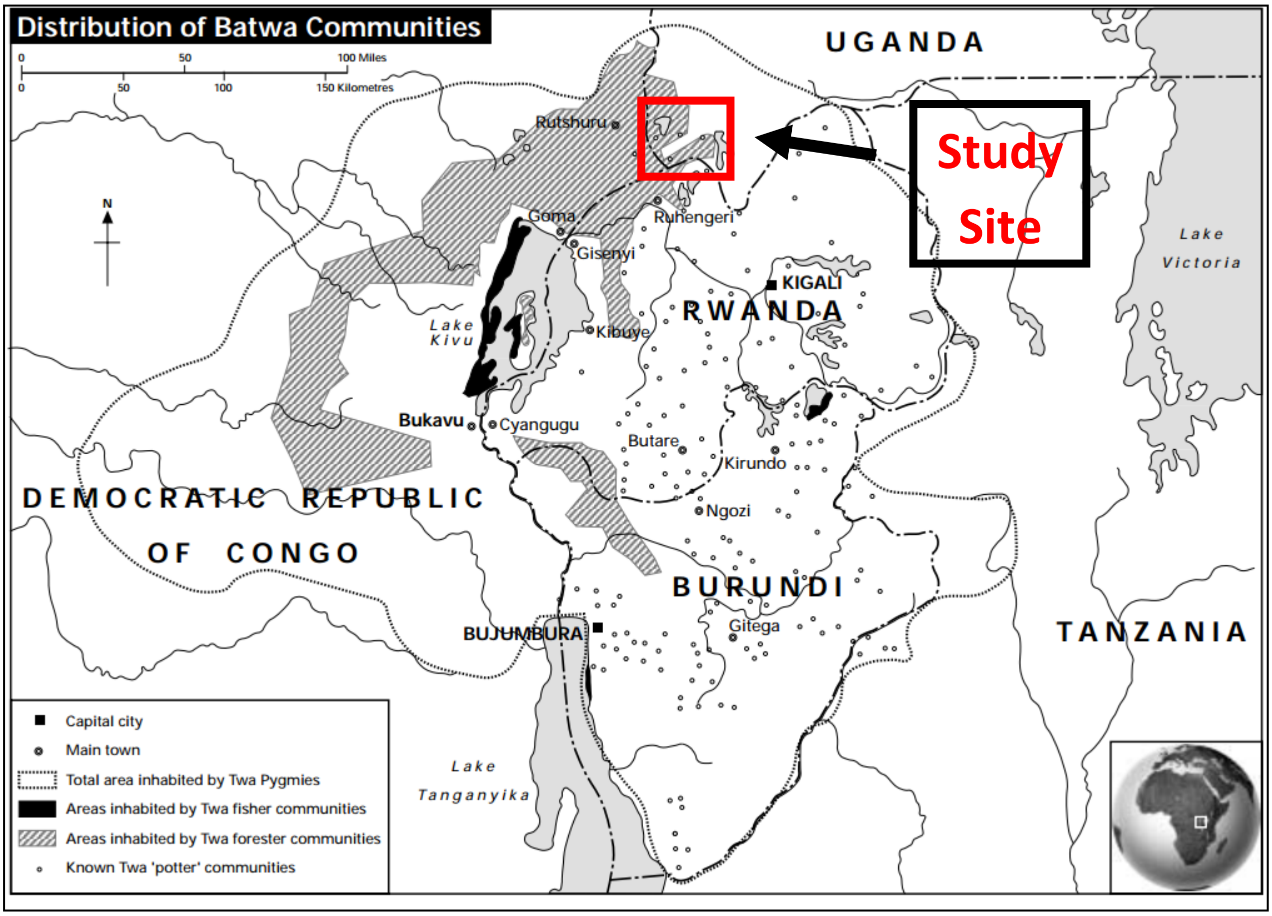


Figure 5.1: Distribution of Great Lakes Batwa communities (from Lewis 2000)

As the intention was to conduct self-funded tri-cultural anthropological research it was important to keep the costs down. During fieldwork in Africa some of the most significant costs were incurred by staff costs, translations in particular. In the UK respondents self-responded, but from whichever traditional community chosen, participants would have to be individually interviewed creating time and money pressures. Due to limited resources it was imperative that a third population was available to be surveyed who lived proximal to the traditional community and could self-respond, conserving time and money. English is the official language of Uganda and while not necessarily widely spoken in rural areas, in the towns of Kabale and Kisoro sufficient people with the linguistic skills to self-respond were recruited. This freed up more time and financial resources to invest in Batwa data collection.

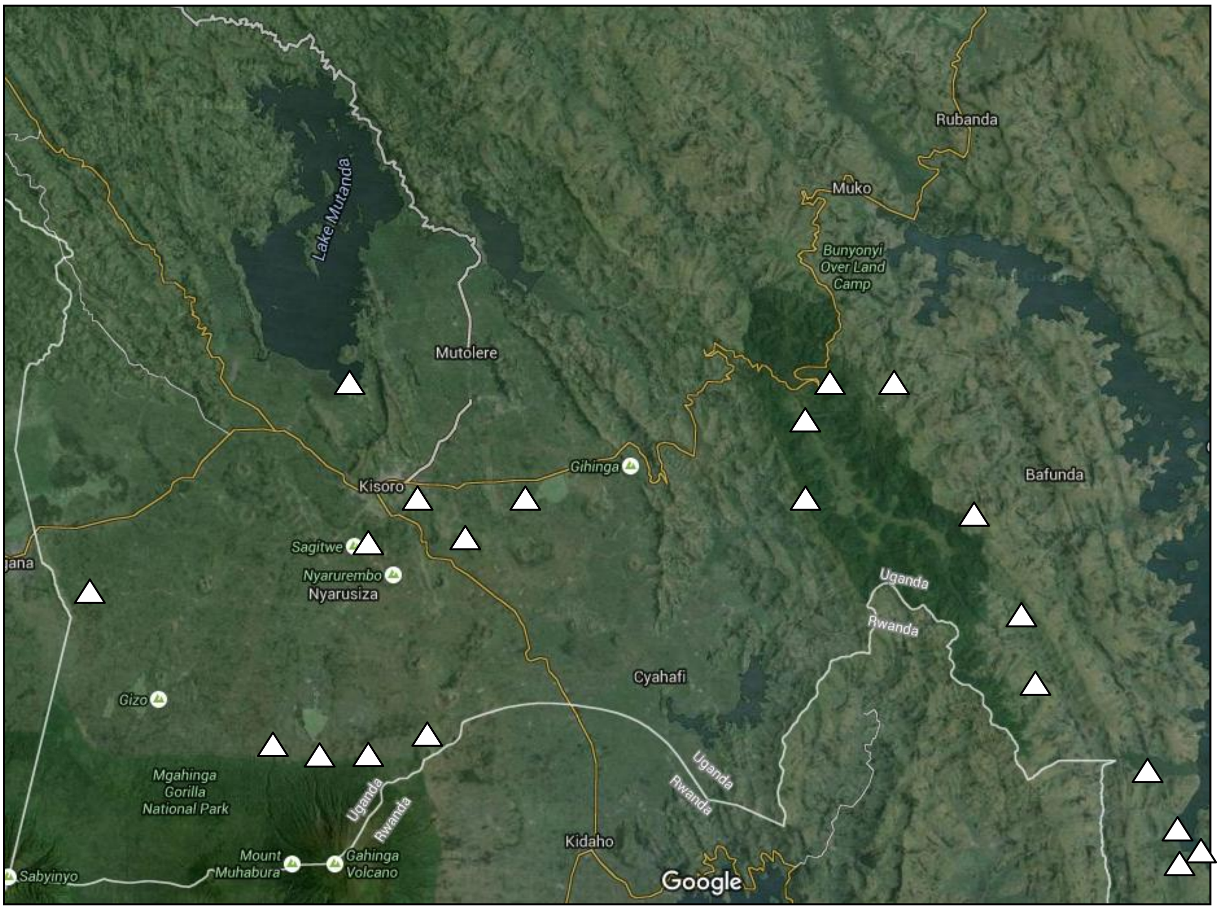


Figure 5.2: A Google Earth snapshot of the study site (white triangles denote Batwa data collection sites)

Another important factor in choosing this area for this research is that between February 1998 and November 1999 I conceptualised, built and then managed an eco-tourism community development campsite at Lake Bunyonyi, on the edge of the study area. Thus there was pre-existing in-depth logistical knowledge of the study area and a long history of positive contact with Batwa communities around Lake Bunyonyi. One former member of staff, Mr Niwagaba Christopher, grew up with Batwa as his neighbours (his family were impoverished marginalised Rwandan refugees fleeing political disturbance and genocide in the 1960s) and is fluent in his local Rutwa dialect (the Batwa language). Chris was employed for this project; during data collection he undertook the role of driver, (secondary) translator and logistician. With this history and local contacts it was possible to organise many of the logistics from the UK; this allied with the lack of culture shock meant that data collection and effective research commenced almost immediately (within 72 hours).

Recruitment and data collection

UK (N=217)

Target participants were residents of the UK aged 18+ who were able to provide informed consent. Investigators attempted to recruit sufficient participants to be able to test for any statistically significant differences between groups; such as those who had children and those who didn't, and inhabitants of rural/urban environments. Investigators also attempted to recruit sufficient participants from a wide range of age groups so as to identify generational differences, if any.

Two different recruitment strategies were deployed during data collection on the UK cohort; direct collection by the lead investigator and a 'snowball methodology' (Malekinejad et al.

2008). Snowball sampling uses a small pool of initial informants or seeds to nominate, through their social networks, other participants who meet the eligibility criteria and could potentially contribute to a specific study. The term 'snowball sampling' reflects an analogy to a snowball increasing in size as it rolls downhill. Snowball sampling can be a useful tool for increasing the numbers of participants but great care needs to be taken when choosing the initial seeds. Snowball sampling is considered to be one of the best data collection methodologies owing to its dependability in collecting relatively reliable, unbiased data (Malekinejad et al. 2008). While snowball sampling has a number of key advantages such as the ability to locate hidden subjects, the primary advantages and reason for choosing it in this case were its ability to generate a relatively random number of subjects in a way that enabled the gaining of required ethical approvals and most importantly the low cost nature of the technique (the resulting 'randomness' was in large part probably a result of the careful choosing of a broad range of primary seeds).

All UK participants, irrespective of how they were recruited, were provided with a self-completing questionnaire and a participant information sheet (shown previously). Both data collection routes aimed to collect data from a broad cross-section of the general public; the route by which each participant was recruited is recorded within the database. The first route, direct collection by the lead investigator (N=73 [~31%]) encompassed the principal investigator directly collecting data from a diverse cross-section of the general public at a range of events and locations. Direct data collection was attempted at numerous locations within Merseyside and Cheshire including the Sydney Jones library at the University of Liverpool, a Cheshire Search and Rescue (CSAR) training event at Delamere Forest (Cheshire), a bridge club in Wallasey (Wirral) and an NCT (National Childbirth Trust) sale in Bebbington (Wirral). At each location those responsible for running the event gave consent for participants to be approached and each participant was required to provide informed consent prior to taking part in the study. Locations were chosen so as to target a broad cross-section of the local community including people without children, parents and the over 60s.

Direct recruitment

During direct recruitment potential participants were asked if they had time to fill out a short questionnaire regarding their attitudes to fire (N=179); many refusals were recorded (N=81). Those who indicated that they had time (N=98) were then informed of the nature and purpose of the questionnaire, assured of its anonymity and asked to participate; further refusals occurred (N=22). Informed consent was obtained from participants by providing them with a participant information sheet (shown previously), which explained any risks associated with participating in the research; to demonstrate that informed consent had been provided all participants had to tick a box at the top of page one of the questionnaire. Participants were explained of their rights to abstain from participation or withdraw consent at any time; this was done both in written form within the participant information sheet and orally by the principal investigator. Consent was recorded along with those who preferred not to participate (non-compliance rates).

Every participant (those who were recruited directly by the lead researcher and also those recruited by primary seeds) was requested to check a box at the beginning of the survey to indicate they had read and understood the information sheet; ticking this box confirmed that informed consent had been provided. Questionnaires from those participants who had not ticked the box were deemed to have not given informed consent and their questionnaires were grouped with refusals and their responses do not appear within the dataset (N=3). No identifiable information was requested from participants and research methods complied with the Helsinki declaration (World Medical Association, 2001).

Indirect recruitment

Indirect recruitment employed a kind of snowball methodology (N=144 [~70%]). Within the snowball data collection route 'primary seeds' were recruited from a range of social and ethnic backgrounds in the North-West, North-East, West Midlands and South-West of England and also the Greater London area. [Secondary] Respondents may have come from a much wider area but the home addresses of respondents were not collected and recorded. Primary seeds were asked to only recruit respondents from the UK. In this study each primary seed received ten questionnaires, ten participant information sheets and one addressed, pre-paid envelope (if required – some seeds declined).

Snowball sampling has been previously criticised for being subject to numerous biases (Heckathorn 1997), but in this case as: i) the only criteria for participation was to be over 18 years of age, able to self-complete the questionnaire, and able to provide informed consent; and ii) great care was made to ensure primary seeds were chosen from both a wide geographical area and a broad socio-cultural base, it is envisaged that the probability of sampling biases being present within the dataset are negligible.

It must be noted that a number of disadvantages are inherent within this methodology. Snowball sampling is reliant on the skill of the individual conducting the actual sampling; in this case it was the first attempt by the principal researcher using this methodology. However in this study this weakness can be effectively mitigated by the very broad eligibility requirements and the great deal of care taken to choose the primary seeds and locations for direct sampling so as to collect an appropriate sample. This care included choosing primary seeds from a number of different demographic and social backgrounds. Primary seeds were not aware of the identity of other primary seeds. Snowball sampling has also previously been accused of generating data that is not an accurate reading of the target population (Heckathorn 1997). Despite snowball sampling beginning with arbitrarily chosen initial subjects or primary seeds, the final composition of the sample can be assessed as being wholly independent of the primary seeds (Heckathorn 1997). As the target population in the initial data collection exercise was drawn from the group 'people over the age of 18 who live in the UK' any sample of 200-300 respondents could potentially be criticised as 'not representing an accurate reading of the target population. After much careful deliberation snowball sampling was seen as the best, cheapest and most efficient way of generating a relatively random dataset with the resources at hand.

Batwa (N=225)

Target participants were any members of the ethnic Batwa who were 18+ and able to provide informed consent. The sampling of Batwa populations was undertaken in Kabale and Kisoro districts in Southwest Uganda. Due to very low levels of literacy and English speaking amongst the Batwa it was decided that all data collection from the Batwa would be undertaken during individual interviews performed in Rutwa (the Batwa language). Prior to going out in the field the entire research team met with two elderly Batwa community leaders at Edirisa's (a local NGO) office in Kabale town to plan the research and create a series of Rutwa translations of the word-pairs that would be used in the interviews. Four fluent tri-lingual (English, Ruchega and Rutwa) Rutwa speakers were present (three ethnic Batwa) and each word was discussed in great detail until everyone had agreed on the appropriate translation. An in-depth discussion was had about the need for two different sets of translations as within the study area were two local tribes with their own language, the Bachega and the Bufumbira, as well as the Batwa; it was agreed that while some very small linguistic differences were present between the Rutwa dialects used (mainly due to some hybridisation of common colloquialisms) across the study area they did not seem to be relevant to the specific translations of the word-pairs. Therefore one list of Rutwa translations were used in this study; presented as Appendix D.

Interviews were conducted by Mr Seriseru Wilbur a 24-year-old Batwa male and native speaker and controlled by Mr Adam Caris (principal investigator). Mr Niwagaba Christopher, a 41-year-old Bachiga male fluent in Ruchiga, Bufumbira, Rutwa, Kyinyarwanda and English was also present at every interview to ensure consistency of translations. In the event that Mr Seriseru Wilbur encountered a translation problem or a lack of understanding about our research methodology then Mr Niwagaba Christopher would step in and help to clarify the situation. Even though Mr Niwagaba and Mr Seriseru had previously never met they had excellent chemistry as a translation team, strengthened by their mutual respect for each other's manner and skill-set.

As the interview was conducted by a 'Mutwa' (the singular form of Batwa) the Batwa were extremely forthcoming and were very happy to provide informed consent, often queuing patiently for more than an hour or two. With the exception of the majority of a small urban Batwa community from Kisoro town all members of the research team were very warmly welcomed at all locations. Once people realised who we were and why we had come, nearly all the people were happy to provide informed consent and then to be interviewed; refusal rate was low (N =22). UK and Non-Batwa Africans received no recompense for participating in this study. However due to the: i) increased time invested by Batwa participants; ii) fact that Batwa feel very marginalised and exploited (both by tourists and NGOs); and, iii) the extreme poverty of many of the villages/settlements we visited, it was decided that a ‘gift’ of a small bar of washing soap would be given to every Batwa participant.

Soap was given for a number of reasons including economic (each bar of soap cost £0.10; ~ 10-20% of the local daily wage) and social (local Bakiga and Bufumbira people commonly perceive Batwa as ‘dirty animals’ - respondents repeatedly stated that being a Mutwa is locally associated with being a despised, dirty and lazy person). Therefore a gift of soap would also help to breakdown local stereotypes and aid integration of the Batwa into the local communities that their expulsion from the forests necessitates; something that has been a difficult tortuous process thus far. With the exception of the inhabitants of a small urban Batwa community from Kisoro town all Batwa were happy with the soap, many of them effusively so. The gift of soap, combined with the fact that a Mutwa conducted interviews, facilitated the easy collection of informed consent and data from Batwa participants; furthermore it made the data collection process both an enjoyable and a rewarding experience for all concerned. Gifts of soap were also provided to those too old or infirm to participate in the research, and those who could not sufficiently understand the research tools and methodology, whose interviews were aborted.

To ensure that the data collected would be in a format that would be easily comparable a data collection tool was designed and developed; this was affectionately termed ‘the stick’ (see Photos F, G, H and I). The stick was a rectangular piece of recycled carpentry timber (mahogany) 600mm long and 80mm wide with a 600mm measuring tape placed at (and eventually nailed to) one side which during interviews was visible to researchers but not to interviewees. Interviewees were given another small stick (obtained locally in each different venue – normally bamboo or wood) with which they could point at 'the stick' to answer questions.

Upon arriving in a Batwa village or settlement we would introduce ourselves, briefly explain the nature of our visit and then ask permission to collect data. Once this had been given on a community basis we would then in more detail explain the nature of the research (including listing the other cohorts involved in the project, the other Batwa communities that had already been surveyed, and the fact that all participants would get exactly the same questions), introduce our research methodology ('the stick') and identify the person we would like to interview first. It was made very clear that all participation was 100% voluntary and that: i) no-one was being forced to participate; ii) any participant could terminate the interview at any time (no-one did); and, iii) we would be happy to answer any questions that any participant or onlooker wished to ask (which we did).

Photo F: Batwa data collection using 'the stick' with Mr Ssemiseru Wilbur translating (Photo taken at Gateera village by Adam Caris)

Photo G: Batwa data collection using 'the stick' with Mr Ssemiseru Wilbur translating (Photo taken at Kagano near to the boundary with Mgahinga NP by Adam Caris)

Photo H: Batwa data collection using 'the stick' with Mr Ssemiseru Wilbur translating (Photo taken at Kanyabukungu by Adam Caris)

Photo I: Batwa data collection using 'the stick' with Mr Ssemiseru Wilbur translating; note the 'evolution of the stick which now has the scale literally nailed on (Photo taken at Murambo village by Adam Caris)

The first interviewee was normally a community leader or someone we could see was intelligent and 'got' what we were trying to do. The first interviewee in any community was very important as other members of the community would watch and learn from them. We quickly learnt that if the first interview went smoothly then subsequent interviews invariably would also; if the initial interview was long and tortuous then some people might 'turn-off' and leave. In some instances we would choose to interview first the people who needed to leave (often the men wanted to go and work in the fields). We specifically aimed to arrive in communities as early as possible so we could find people before they left for their fields; Sunday, a day of rest, was also heavily utilised for data collection, as we would find villages and settlements full of people.

Once an interviewee had been selected, we reiterated to them in detail that: i) all participation was entirely voluntary; ii) they were welcome to ask questions at any time; iii) they could stop being interviewed at any time; and, iv) except the soap they were not being paid for their participation. Participants were then asked whether they were happy to commence with the interview. Once informed consent had been confirmed a demonstration of the research methodology (‘the stick’) was undertaken. Then to test the level of understanding participants had of ‘the stick’ the question ‘*do you like meat or honey more?*’ was asked. After they had responded the full variety of different answers were then explained to the participant so that they could clearly see how to provide highly nuanced answers. When using ‘the stick’ all answers were confirmed verbally, and if there was any mismatch between the two answers the answer was not recorded and the question was asked again.

It was immediately apparent when participants were struggling to answer correctly. If any suspicions were raised the principal investigator would ask for specific questions to be repeated so that the new answer could be crosschecked with the original answer. If these didn’t match then ‘the stick’ was re-explained and the interview re-started from the beginning. In one case the interviewee was a very old lady (self proclaimed 98 years old) who clearly did not grasp how to use ‘the stick’; the interview was completed so as not to embarrass the participant, but the data does not appear within the dataset. However, post interview she continued to give very clear insights to the old way of life within the forest and specifically the important role played by large communal fires. The feedback from using the stick was very positive and due to its very simple nature it was identified by Mr Seriseru to have been a very popular experience for the Batwa and not intimidating at all. Questions not requiring the stick were answered verbally with answers recorded on individual questionnaire sheets.

Non-Batwa Africans (N=219)

Target participants were any Non-Batwa black (mostly Bantu) Africans who were 18+, able to understand and self-complete the questionnaire in English, and able to provide informed consent. Due to the fact that we were looking for a very different African population (from the Batwa) to compare against both the UK population and the Batwa population, combined with the economic and time constraints placed upon the research team, it was decided to collect data from Non-Batwa Africans only in English. English is the official language of Uganda, all education after primary school year 5 is provided in English; in Ugandan towns and cities English is very widely spoken. However one exception was made to this, when during a trip to a traditional forge, two blacksmiths were interviewed in Ruchiga by Mr Niwagaba Christopher (using pre-prepared and triple-verified Ruciga translations) using 'the stick'. All other respondents were provided with a questionnaire and a participant information sheet and, after a comprehensive briefing, asked to self-fill their questionnaire. Respondents were recruited in groups of between 3 and 10 and were supervised when completing the questionnaire so that any questions they had could be answered and any required assistance could be provided (see Photo J). Support staff were aware, and had undergone training to deal with the concept, that while the linguistic capability of respondents may be sufficient, participants might be unfamiliar with this kind of survey data collection.

Staff and students from Kabale University (N=176) make up the majority of the Non-Batwa African group (N=219) with other participants coming from offices, social clubs and tourism operations in Kisoro town, Kabale town and surrounding environs. The refusal rate of Non-Batwa Africans was the highest of the three groups (N=127); seemingly mainly due to the fact that participation was not being recompensed. Two full days were spent at Kabale University by the research team consisting of Mr Niwagaba Christopher, Mr Jimmy Brown (a

31 year old Bachiga male and alumni of Kabale University) and the Principal investigator Mr Adam Caris. Prior to commencing data collection permission was requested and granted by Professor Joy Kwesiga, Vice-Chancellor of Kabale University, to collect data within the Kabale university campus; all students provided informed consent in the same way as participants from the UK study prior to self-completing the questionnaire. A significant part of a further 3 days was spent recruiting and gathering NBA data.

Photo J: A small group of five self-responding Non-Batwa Africans (NBA) from Kabale University completing surveys with Mr Niwagaba Christopher (white checked shirt) on hand to answer questions and make sure that respondents were happy and understood the data collection methodology (Photo by Adam Caris)

Data analysis

Data were entered into a dedicated database using SPSS 22. Both the paper questionnaire and 'the stick' deliberately had no scale observable to participants so as to obtain a more neutral (uninfluenced by seeing numbers) set of results. In section one of the questionnaire, where respondents had self-completed the questionnaire, the data was numericised using a 15cm ruler. The relative strength of feeling was measured in mm using a scale of 1-120; where 1 and 120 represent the strongest views and 60 being the equal point. Where respondents had been individually interviewed using 'the stick' (all of the Batwa and two of the Non-Batwa Africans) data had been recorded on a scale of 1-60 (with 30 being judged as the equal point) which was then recalculated to a scale of 1-120 resulting in a 50% decrease in the level of variation within the individually entered data (by doubling each score odd numbers were removed from the data).

Statistical issues arising from the demographic make-up of the different cohorts

Once responses from the Batwa cohort were placed into SPSS and analysis commenced it became apparent that issues existed with the distribution of data in some key demographic variables (e.g. rural/urban). In a binary system (where two responses are possible – e.g. male/female, burnt/not burnt) if data is fairly normally distributed (e.g. 50/50 split or 60/40 split) then a sample size of ~N=220 should be sufficient to test for the presence of significant relationships (Field 2013). However the nature of Batwa society and lifestyle shows that many of the key demographic indicators, which had fairly balanced responses in the UK cohort (table 6.1), were not balanced in the Batwa cohort. This is because of societal and cultural differences and not because the Batwa were unable to understand the questions or data collection methodology sufficiently to provide accurate answers.

Being forest-dwelling hunters and gatherers, only recently displaced from their ancestral forests, only a very small number of Batwa had migrated to nearby towns instead ‘choosing’ to reside in areas peripheral to their former forest habitats (often in recently deforested environments). In the town of Kisoro, the administrative centre of Kisoro District, three small urban communities exist. All three communities were visited, but at the largest settlement only two Batwa were willing to be interviewed. In this settlement all other Batwa demanded money and/or alcohol (despite the research team arriving at 6:08am), demands that were politely refused before researchers quietly left. This lack of urban migrants resulted in between ~95% of Batwa responding ‘rural’; ‘under 10 living environment’ (96.0%), ‘adolescent living environment’ (95.1%) and ‘current living environment’ (95.6%). Thus only 4-5% of respondents answered ‘urban’ to any question. The sample size of 225 coupled with this level of data imbalance does not seemingly allow the possibility of identifiable statistical significance being identified when testing for the impacts of demographic variables. Interestingly, while postulated prior to surveying to be very significant, UK cohort results show that zero statistically significant relationships were observed between the eleven word-pairings of Q1 and responses to the three ‘living environment questions’ (see Table 6.14); NBA results also showed very few statistically significant relationships.

Where this lack of balance within the responses of the Batwa cohort is perhaps most pertinent to addressing some of the central research questions of this study is the area of the breadth of a respondents’ personal ‘fire-use history’ (Q2). In the UK cohort (as will be shown and discussed in detail later in this report), on seven out of eleven occasions, this was observed to be significant to how participants responded to the word-pairings in Q1 (Table 6.14); this was the most of any variable and accounted for one third (7/21) of all of the statistically significant relationships identified within the UK cohort from Q1. Within the Batwa cohort

0.0% identified as ‘low-users’ (1-3 different uses) down to the fact that 100% of people had used fire for: ‘cooking food’, ‘keeping warm’, ‘lighting’ and ‘boiling water’; only 0.9% (2 respondents) identified as ‘medium-users (4-7 different uses). 99.1% classified as ‘high-users’ (Table 6.15) making it worthless to test Batwa responses to the word-pairings from question one for significance against this variable.

None of the data from this study (all three cohorts included) can be described as parametric data; it is all non-parametric. Therefore non-parametric statistical analysis in the form of Kruskal-Wallis testing has been deployed here rather than an ANOVA. To use an ANOVA it is assumed that the distribution of each data-set is ‘normal’ and that approximately equal variance exists within the results for each group (Field 2013) which is not the case within the raw data collected in this study. However when using Kruskal-Wallis tests these assumptions do not exist (Field 2013). Chi-squared statistics are used to compare data.

Demographic imbalances within certain key variables (particularly from the Batwa data-set) to Kruskal-Wallis testing meant that the potential for statistically significant relationships to be identified was dramatically reduced, also reducing the overall capacity of this research to illuminate evolutionary relationships with confidence. As zero chance existed to find statistically significant responses these analyses are thereby omitted from the data presented in the Batwa results. These issues and issues arising from some of the demographic variables are discussed further later in this chapter.

Refusals

In this study the total number of people directly approached was 937 (UK = 323, Refusals = 106, ~33%; Batwa = 268, Refusals = 42, non-usable data = 1, ~16%; NBA = 346, Refusals =

127, ~41%) with an overall total number of refusals of 275 and one non-usable data leaving 661 usable respondents (overall refusal rate = ~29%). This figure only includes those directly approached by researchers with the exception of two questionnaires, which arrived without the consent box having been ticked; these were both classified as 'refusals'. The refusal rate from the UK snowball collection method was not calculable.

New Variables

For the purposes of conducting certain aspects of the data analyses seventeen new variables were created to assist with data analysis and to help observe relationships between variables. As well as new variables, the age group boundaries were altered slightly from those provided in the questionnaire. Originally seven age groups were provided (18-24; 25-34; 35-44; 45-54; 55-64; 65-74 and 75+). Due to the very low numbers of respondents in the 75+ group a new category of 65+ was created reducing the number of age groups to six. Furthermore whilst analysis was conducted using each individual fire-use category, to be able to view the breadth of fire-use experience of each individual participant, a new variable was created using the number of types of fire-use recorded as having been experienced by each respondent. Out of a total of ten potential different fire-uses (e.g. boiling water, cooking food, keeping insects away) if a respondent had reported 1-3 different uses this was recorded as 'low usage', 4-6 was recorded as 'medium usage', and 7-10 was recorded as 'high usage'.

The smoking data was used to create a new variable termed 'smoking status', which incorporated three categories: current smokers, ex-smokers, and never smoked. The 'burning' data was also reformulated into three new categories to aid data analysis: slightly burnt (1-40), moderately burnt (41-80) and severely burnt (81-120). When conducting interviews with the Batwa any response >40 to the question of '*How badly burnt*?' was followed by a question of ‘what happened?’ and a request for a description of injuries; this was precipitated by a surprisingly (to the principal researcher) relatively high number of very severe burns. The data on children was also placed into three categories: No children, children < 18 and children18+. All of these new variables were created so as to illuminate relationships between these factors and perceptions of risk around fire.

Eleven new ‘ternary’ variables were created to be able to perform Cross-Tabs analysis. Within these variables termed ‘ORs’ (e.g. ‘safeORscary’) all results of 55-65 were classified as ‘evenish’ as some people who wanted to produce a balanced or deliberately indecisive response may have had difficulty estimating the exact middle point of the scale. Results <55 and >65 were deemed to show a decisive result or a preference for that emotion.

Chapter 6 – Surveying modern human attitudes to fire - Results

This chapter presents the results of the analyses set out in full. Results are presented by cohort: the UK data first (C1), then data from the Batwa cohort (C2) and finally the non-Batwa African (NBA) data (C3). Finally a synthesis of the results is presented with a brief discussion of whether postulates and null hypotheses had been rejected or not.

C1 – The UK cohort

Of the 217 people recruited to make up the UK population 95 (43.8%) were male and 122 (56.2%) were female. 104 people had no children (47.9%), 49 respondents had their youngest child under the age of 18 (22.6%) and 64 people responded that their youngest child was 18+ (29.5%). 117 people stated that they had never smoked (53.9%), 23 were current smokers (10.6%) and 77 people classified themselves as ex-smokers (35.5%). 118 people stated that they had never been burnt (54.4%) while 99 stated that they had (45.6%); of those who said they had been burnt 82 (82.8%) classified their most serious burn as 'slight' (1-40), 14 (14.1%) as 'moderately serious' (41-80) and 3 people (3.0%) as 'severe' (81-120).

Of the ten different fire-uses that we specifically asked respondents if they had personal experience of, the most frequent affirmations were 'cooking food' (94.5%) and 'keeping warm' (96,3%). Signalling (4.1%) and killing plants (19.8%) were the only fire-uses that less than twenty percent of UK respondents admitted to having experience of. When the total number of different fire-uses were collated and placed into three categories (Low [1-3], Medium [4-7] and High [8-10]) 44 respondents were classified as 'Low' (20.3%) 118 as 'Medium' (54.4%) and 55 as 'High' (25.3%). Please note that the frequency of experience was not requested or collected – only whether each respondent had personal experience of that particular fire-use (i.e. it is possible that some respondents classified as 'low' may have extensive experience of fire within a narrow range of fire-uses and vice versa).

In hindsight the frequency of experience would have been very valuable data which would have enabled a new dataset to be created thus potentially affording significant new insights. However, it would also have singinicantly extended both the length of the questionnaire beyond its current two pages and the length of time for interviews; either of which could significantly have reduced participation levels and thus the total amount of data collected. With the benefit of hindsight this would perhaps have been done differently; as would many other aspects of this study.

Frequencies

Data analysis shows that of the UK respondents 62 (28.6%) classified their 'under 10 living environment as predominantly 'rural', while 155 (71.4%) classified as predominantly 'urban'. This altered to 60 rural (27.6%) and 157 urban (72.4%) from the 'age 10 to age 18 living environment' question. When questioned about their 'current living environment' 49 people classified as rural (22.6%) and 168 as urban (77.4%). Data was filtered into six different age groups (see table 6.2). The largest group was 18-24 (21.7%), with the smallest group being the 45-54 (12.9). The distribution resembles a population pyramid from a highly developed country (Korenjak-Černe et al. 2014). The age distribution is seemingly in accord with what would be expected of a random cross-section of the UK population.

Category	Variable	UK
	N	217
		%
Sex	Male	43.8
	Female	56.2
Parenthood	No children	47.9
	Children under age 18	22.6
	Adult children	29.5
New Age	18-24	21.7
	25-34	18.4
	35-44	16.6
	45-54	12.9
	55-64	17.1
	65+	13.4

Smoking status	Never smoked	53.9
	Ex-smoker	35.5
	Current smoker	10.6
Burnt or not	No	54.4
	Yes	45.6
How badly burnt	Numbers burnt **(not %)**	N = 99
This data only looks at those who answered that they had been burnt	Slightly	82.8
	Moderately	14.1
	Severely	3.0
Fire-uses individual (% yes)	Keeping insects away	33.6
	Cooking food	94.5
	Keeping warm	96.3
	Lighting	64.1
	Signalling	4.1
	Cleaning and cleansing	21.2
	Boiling water	79.3
	Killing plants	19.8
	Burning rubbish	70.5
	Making things	29.0
Fire usage combined	Low Usage (1-3)	20.3
	Medium Usage (4-6)	54.4
	High Usage (7-10)	25.3
Under 10 living environment (predominant)	Rural	28.6
	Urban	71.4
Age 10 to 18 living environment (predominant)	Rural	27.6
	Urban	72.4
Current living environment	Rural	22.6
	Urban	77.4

Table 6:1: Frequencies of certain demographic descriptors from the UK sample (N=217)

	Frequency	Percent (%)
18-24	47	21.7
25-34	40	18.4
35-44	36	16.6
45-54	28	12.9
55-64	37	17.1
65+	29	13.4

Table 6:2: The Frequency of different age groups within the UK sample

Means

An analysis of the eleven word-pairings from section one of the questionnaire (answers were numericised from 1-120, giving a possible maximum range of 120) found that responses were diverse with the range of answers exceeding 110 (out of a possible 120) for all the questions except for the word-pairing ‘protective/risky’ whose range of 99 is attributable to the minimum recorded value of 20. All of the standard deviations fell within the range of 24-31. It should be reiterated that these word-pairings were specifically chosen as NOT to be exact opposites of each other, but rather to allow respondents to choose between either a positive or negative emotion/connotation

	Range	Minimum	Maximum	Mean		Std. Deviation	Coefficient of variance	Median
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic		
PROTECTIVERISKY(rev)	99	20	119	84.968	1.749	25.771	0.303	91.0
EXCITINGDANGEROUS	117	3	120	75.866	2.067	30.442	0.401	79.0
WARMINGBURNING(rev)	116	2	118	55.410	1.960	28.875	0.521	58.0
SOCIALVIOLENT(rev)	116	3	119	59.410	1.983	29.218	0.492	60.0
SAFESCARY	116	4	120	71.230	1.801	26.533	0.372	64.0
USEFULHAZARDOUS(rev)	115	3	118	55.373	1.923	28.328	0.512	58.0
COMFORTINGSTRESSFUL	113	3	116	38.290	1.702	25.073	0.655	35.0
FRIENDLYFEARSOME	115	3	118	58.719	1.825	26.888	0.458	59.0
GIFTTHREAT	116	3	119	60.005	1.888	27.816	0.464	60.0
ATTRACTINGREPELLING	116	2	118	46.046	1.717	25.296	0.549	46.0
CLEANSINGDESTRUCTIVE	112	7	119	78.184	1.645	24.240	0.310	80.0

Table 6.3: Mean averages and related statistics for the UK sample (N=217)

For any word-pairing a mean of > 60 denotes that, on average and within that word-pairing, respondents’ associated negative rather than positive emotions or attitudes towards fire; in effect framing fire negatively. While a mean of < 60 denotes that on average respondents’ associated positive rather than negative emotions or attitudes towards fire within that word-pairing; in effect framing fire positively. The more distant the mean value is from 60 denotes the greater preference the population has for one word over the other. Observation of the data shows that the most ‘positive’ feeling about fire felt by the UK cohort was ‘comforting’ (from the ‘comfortingstressful’ word-pair) with a mean of 38.290, while the most ‘negative’ was 'risky' with a mean of 84.968 (from the word-pair 'protectiverisky'). The word-pairs that elicited on average the most balanced responses were 'giftthreat' with a mean of 60.005 and 'socialviolent(rev)' with a mean off 59.410.

The UK cohort clearly displays the positives and negative attributes of fire. Results from the UK cohort can be classed as 'a mixture of positive and negatives'. Two out of eleven word-pairings had a mean and median value both less than 50 (comfortingstressful and attractingrepelling) (Table 6.3), which can be classed as 'positive'. In addition a further two word-pairings had a mean of ~55 paired with a median < 60 (warmingburning[rev] and usefulhazardous[rev]), which can be classed as 'slightly positive'. A further three word-pairings (SocialViolent[rev], friendlyfearsome and giftthreat) had a mean and a median of ~60, which can be classed as 'neither positive or negative'. Four word-pairings had a mean > 70 (three of which had a median > 70) (Table 6.3) which can be classed as 'negative'; one of which protectiverisky(rev) (mean = 84.968, median = 91.0) can be seen as 'highly negative'. This mixture of results, coupled with the well-balanced demographic frequencies displayed in Table 6.1 provides an excellent baseline to compare the other two populations (Batwa and Non-Batwa Africans).

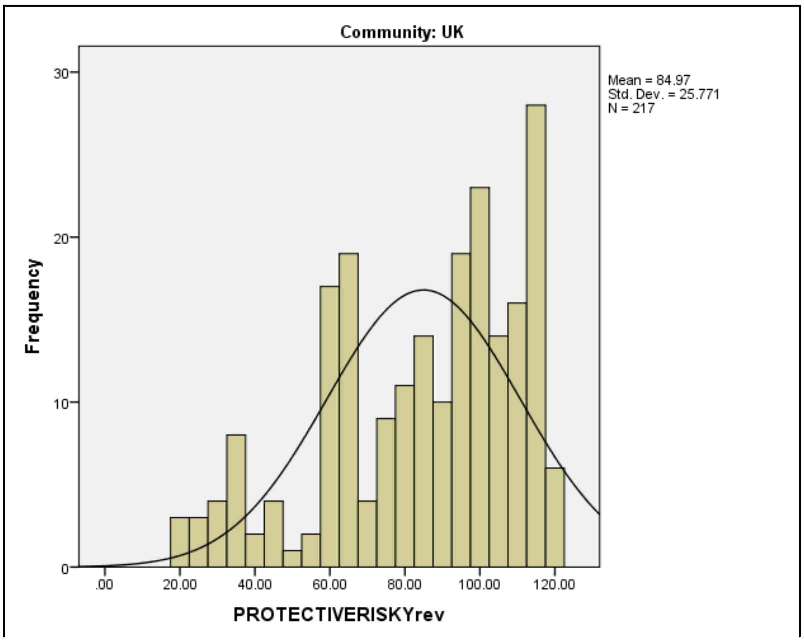
All of the results from the UK cohort word-pairings were not normally distributed and therefore statistical analysis specific to non-normally distributed data were applied. Most data distributions could be described as multi-modal but on occasions bi-modal and tri-modal distributions were observed.

ProtectiveRisky(rev)

The mean response was 84.97 (Std.dev = 25.771), the median was 91.0 and at least three modes or clusters of data are clearly visible (Fig. 6.1). A strong preference for 'risky' within the UK cohort is reflected in Fig. 6.1 with a large cluster or mode of data points within the 90-120 range correlating to respondents suggesting they perceived fire as being much more risky than protective. A second smaller mode clustered around the 55-65 range representing respondents who perceived fire as being both protective and risky. The third (smallest) mode represents respondents who viewed fire as being much more protective than risky.

A further breakdown of the data accounting for sex, parenthood and whether people classify themselves as having been burnt or not shows different trends within the data; male data being more normally, broadly and evenly distributed than data provided by female respondents (Fig. 6.2). Analysis shows that females who self-responded that have never been burnt perceive fire as being most risky, respondents who have been burnt observed fire to be more protective than those who have not (Fig. 6.2).

Figure 6.1: A histogram of the frequency of responses from the UK cohort to ProtectiveRisky(rev)



Patterns visible within Figs. 6.2 and 6.3 are supported by Kruskal-Wallis non-parametric testing (See Table 6.4), with significant findings being observed when sex differences (p=0.003), whether respondents had been previously burnt (p=0.016) and the effect of age (p=0.008) are analysed (Fig. 6.3). Kruskal-Wallis non-parametric testing showed no significant differences related to living environments, parenthood and smoking (Table 6.4).

Figure 6.2: A histogram of the frequency of responses from the UK cohort to ProtectiveRisky(rev) filtered for: i) sex of the respondent; and ii) whether they had previously been burnt by fire or not

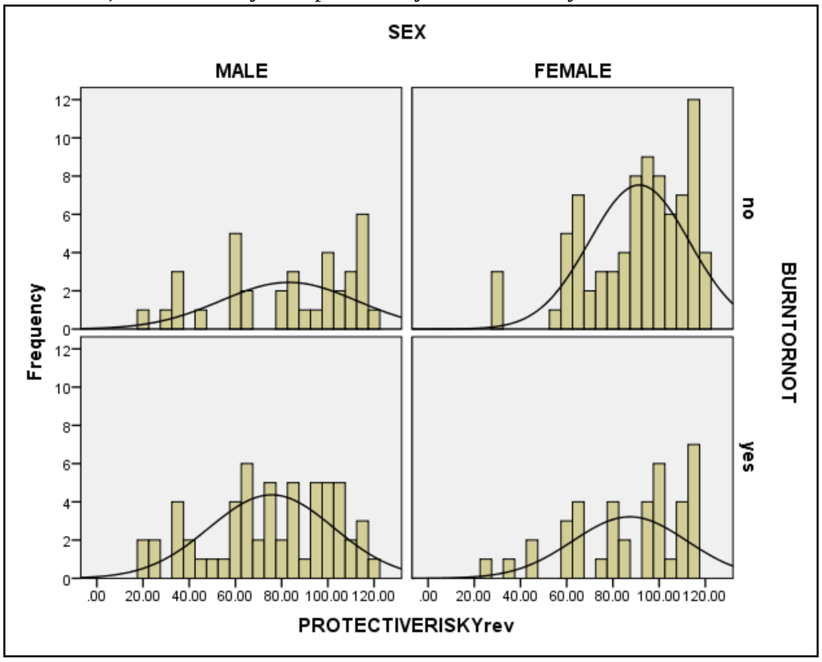
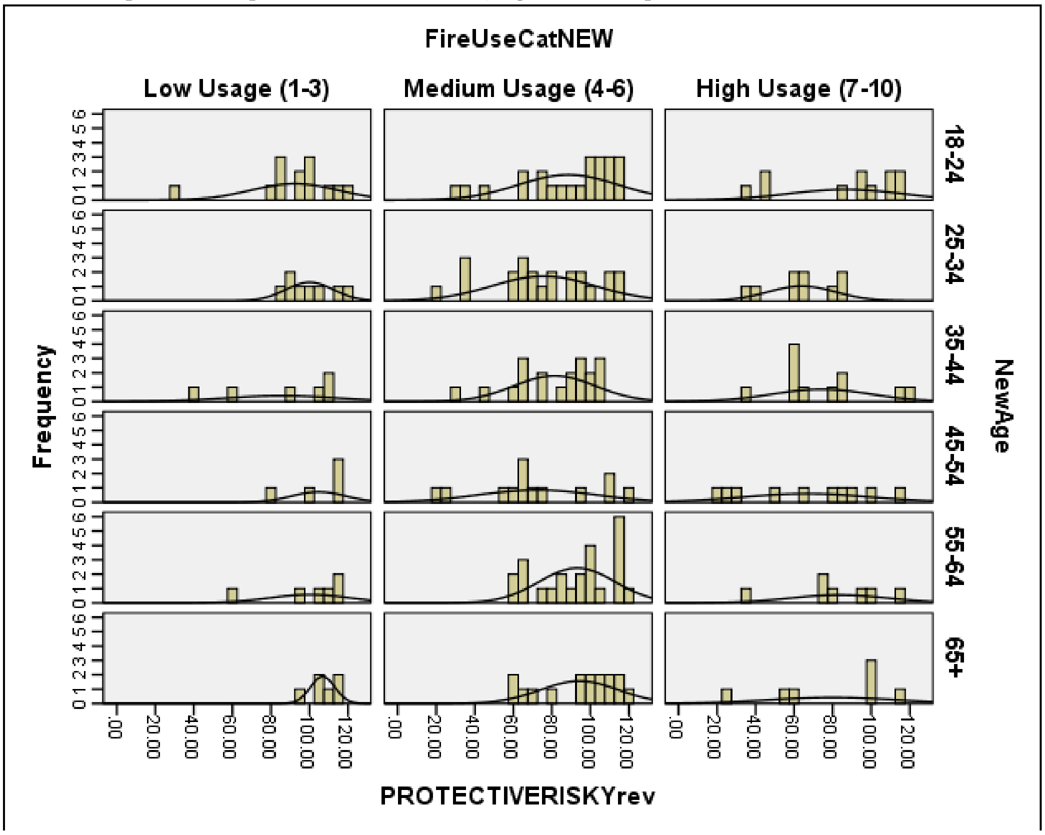


Figure 6.3: A histogram of the frequency of responses from the UK cohort to ProtectiveRisky(rev) filtered for: i) the breadth of their previous experience of fire; and ii) age of the respondent



	SEX	N	Mean Rank		
PROTECTIVERISKYrev	MALE	95	94.74	Chi-Square	8.723
	FEMALE	122	120.11	df	1
	Total	217		Asymp. Sig.	0.003
	BURNTORNOT	N	Mean Rank		
PROTECTIVERISKYrev	No	118	118.42	Chi-Square	5.829
	Yes	99	97.77	df	1
	Total	217		Asymp. Sig.	0.016
	PARENTHOOD	N	Mean Rank		
PROTECTIVERISKYrev	NO	104	107.51	Chi-Square	0.113
	YES	113	110.37	df	1
	Total	217		Asymp. Sig.	0.737
	NewAge	N	Mean Rank		
PROTECTIVERISKYrev	18-24	47	120.3		
	25-34	40	90.08	Chi-Square	15.704
	35-44	36	92.35	df	5
	45-54	28	93.36	Asymp. Sig.	0.008
	55-64	37	125.62		
	65+	29	131.36		
	Total	217			
	Smokingstatus	N	Mean Rank		
PROTECTIVERISKYrev	never smoked	117	112.58	Chi-Square	0.89
	ex-smoker	77	103.94	df	2
	current smoker	23	107.72	Asymp. Sig.	0.641
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
PROTECTIVERISKYrev	RURAL	62	107.28	Chi-Square	0.065
	URBAN	155	109.69	df	1
	Total	217		Asymp. Sig.	0.799
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
PROTECTIVERISKYrev	RURAL	60	106.32	Chi-Square	0.152
	URBAN	157	110.03	df	1
	Total	217		Asymp. Sig.	0.697
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
PROTECTIVERISKYrev	RURAL	49	99.06	Chi-Square	1.587
	URBAN	168	111.9	df	1
	Total	217		Asymp. Sig.	0.208
	FireUseCatNEW	N	Mean Rank		
PROTECTIVERISKYrev	Low Usage (1-3)	44	139.22	Chi-Square	16.922
	Medium Usage (4-6)	118	107.94	df	2
	High Usage (7-10)	55	87.1	Asymp. Sig.	0.001

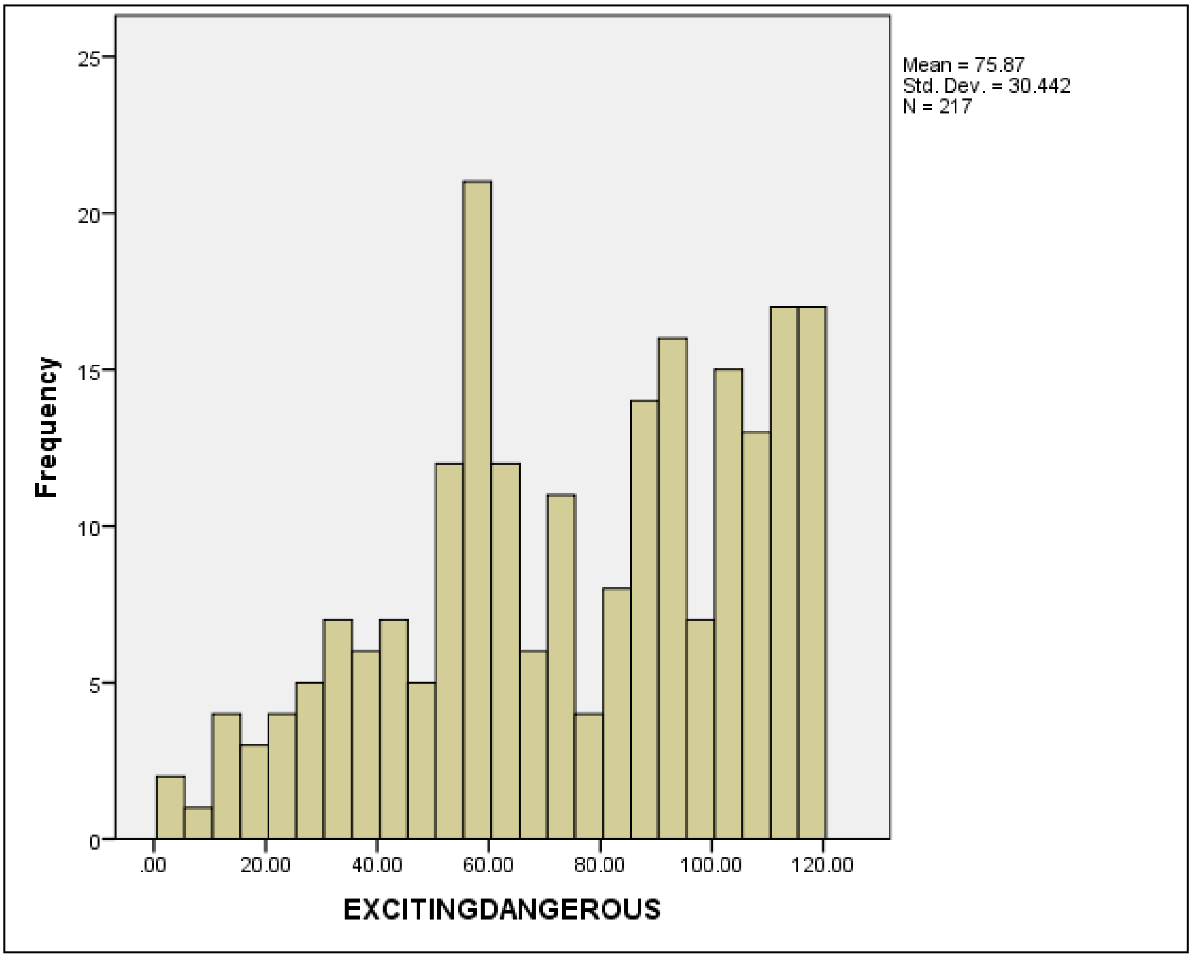
Table 6.4: Kruskal-Wallis test data with ProtectiveRisky (rev) as the test variable and a number of demographic grouping variables

When accounting for differences between people with histories of low medium and high fire usage, Kruskal-Wallis non-parametric testing showed very significant differences ($p<0.001$), clearly visible (Fig. 6.3), demonstrating that particularly within female populations the greater the history of fire usage then the more protective and less risky fire is perceived. This data clearly supports the idea that the greater a person's experience with fire then the less riskily fire is perceived.

Fig. 6.3 shows a number of clear trends. Within the 'Low usage' and Medium usage' categories as age increases from 25 respondents appear to perceive fire as being more risky and less protective. This trend is also apparent in the 'High usage' category but is somewhat less visible, possibly due to the small number of respondents in this group (N=55). Within the 'High usage' category, the age group 18-24 had a distribution more similar to those recorded for participants aged over 55 than those aged 25-54 (Table. 6.4).

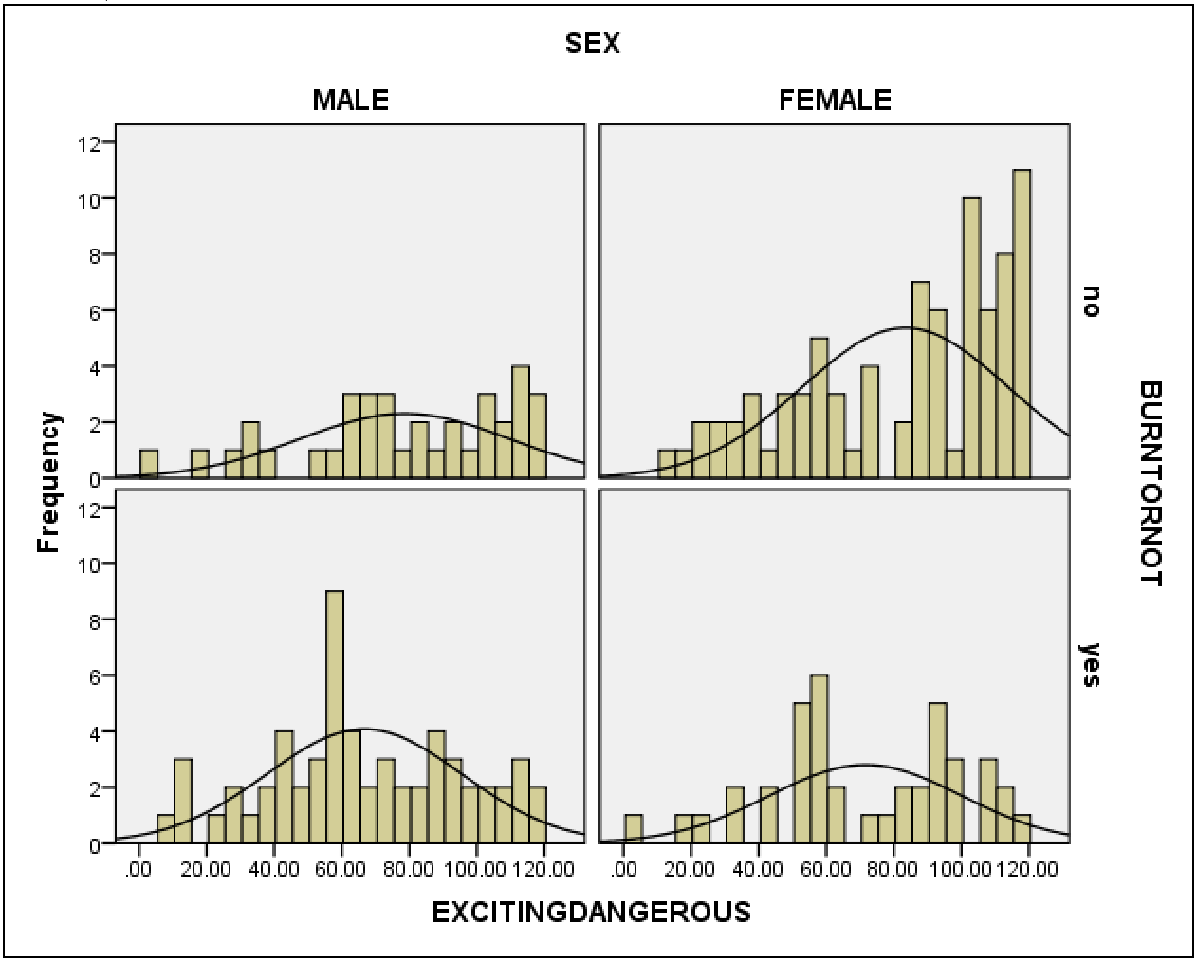
ExcitingDangerous

Figure 6.4: A histogram of the frequency of responses from the UK cohort to ExcitingDangerous



The mean for the UK cohort was 75.87 (Std. Dev. = 30.442) and the median was 79.0 showing that the UK cohort perceived fire as being more dangerous than exciting (Fig. 6.4). Despite this a big mode exists in the range 50-70 demonstrating that a large number of respondents had very balanced views between exciting and dangerous (Fig. 6.4). A multi-modal distribution exists within the data with the largest mode of respondents (80-120) answering that they found fire to be more dangerous than exciting. The 80-120 mode is populated by 'never-burnt' females (Fig. 6.5), females over 35 (Fig. 6.6), and people with children and low or medium fire-use experience (Fig. 6.7).

Figure 6.5: A histogram of the frequency of responses from the UK cohort to ExcitingDangerous filtered for: i) sex; and ii) burnt or not



Kruskal-Wallis testing observed that significant differences occur between populations who have been burnt or not (χ^2 =12.044; p=0.001) (Fig 6.5). Males were identified as being more

Figure 6.6: A histogram of the frequency of responses from the UK cohort to ExcitingDangerous filtered for: i) sex; and ii) age

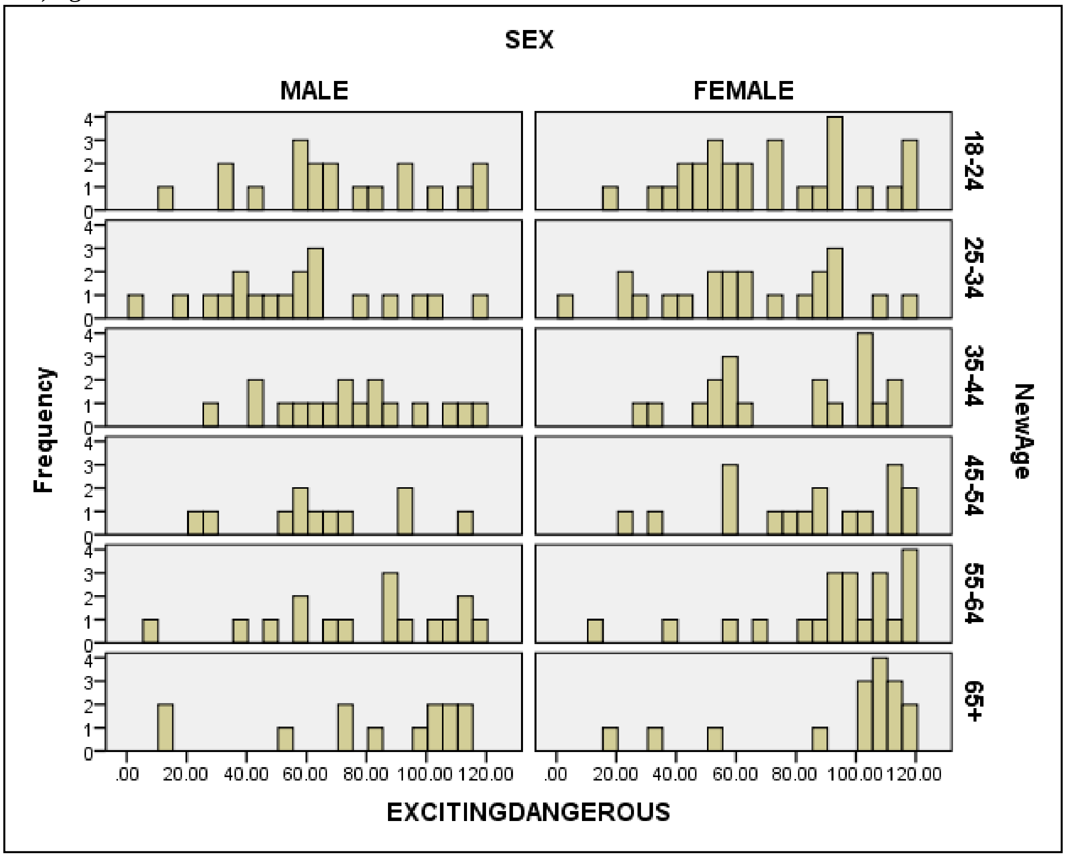
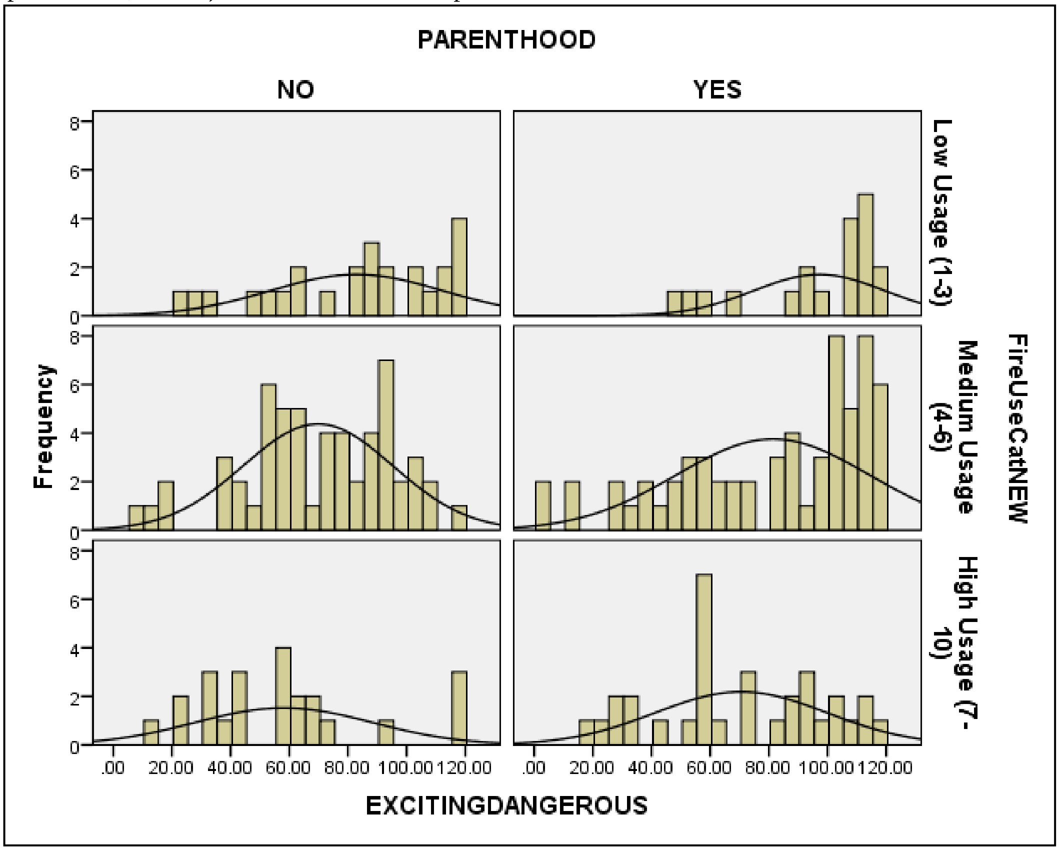


Figure 6.7: A histogram of the frequency of responses from the UK cohort to ExcitingDangerous filtered for: i) sex; ii) parenthood; and iii) breadth of fire-use experience



likely to find fire exciting or to rate fire as both exciting and dangerous if they have previously been burnt. Females were more likely to have strong views in favour of fire being dangerous if they have not been previously burnt.

Differences between different age groups were also statistically significant (χ^2 =21.795; p=0.001) (Table 6.5). The clear trend is that younger people found fire to be most exciting (Fig. 6.6); those in the 25-34 age group had the lowest Mean Rank (Table. 6.5), with fire seen as increasingly dangerous with every age group older than 25-34. This trend is most evident within the female cohort. Statistically significant differences were also obtained for the variables 'Parenthood' (χ^2 =7.456; p=0.006) and those who had low, medium or high levels of fire-use (χ^2 =14.616; p=0.001) (Table 6.5); these variables, plotted against each other (Fig 6.7) display clear trends within the data. As the breadth of fire-use experience increases respondents increasingly shifted from seeing fire as very dangerous and not exciting to increasingly less dangerous and more exciting; this trend is particularly noticeable amongst males, but is also evident amongst the female cohort.

	SEX	N	Mean Rank		
Exciting Dangerous	MALE	95	99.75	Chi-Square	3.671
	FEMALE	122	116.20	df	1
	Total	217		Asymp. Sig.	0.055
	BURNTORNOT	N	Mean Rank		
Exciting Dangerous	no	118	122.55	Chi-Square	12.044
	yes	99	92.85	df	1
	Total	217		Asymp. Sig.	0.001
	PARENTHOOD	N	Mean Rank		
Exciting Dangerous	NO	104	96.87	Chi-Square	7.456
	YES	113	120.16	df	1
	Total	217		Asymp. Sig.	0.006
	NewAge	N	Mean Rank		
Exciting Dangerous	18-24	47	99.14		
	25-34	40	78.48	Chi-Square	21.795
	35-44	36	107.42	df	5
	45-54	28	110.80	Asymp. Sig.	0.001
	55-64	37	132.08		
	65+	29	137.86		
	Total	217			

	Smokingstatus	N	Mean Rank		
Exciting Dangerous	never smoked	117	108.43	Chi-Square	0.765
	ex-smoker	77	112.63	df	2
	current smoker	23	99.76	Asymp. Sig.	0.682
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
Exciting Dangerous	RURAL	62	111.47	Chi-Square	0.134
	URBAN	155	108.01	df	1
	Total	217		Asymp. Sig.	0.714
	ADOLESCENTLIVING ENVIRONMENT	N	Mean Rank		
Exciting Dangerous	RURAL	60	102.10	Chi-Square	0.202
	URBAN	157	107.82	df	1
	Total	217		Asymp. Sig.	0.653
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
Exciting Dangerous	RURAL	49	109.02	Chi-Square	0.000
	URBAN	168	108.99	df	1
	Total	217		Asymp. Sig.	0.988
	FireUseCatNEW	N	Mean Rank		
Exciting Dangerous	Low Usage (1-3)	44	136.41	Chi-Square	14.616
	Medium Usage (4-6)	118	108.62	df	2
	High Usage (7-10)	55	87.88	Asymp. Sig.	0.001

Table 6.5: Kruskal-Wallis test data with ExcitingDangerous as the test variable and a number of demographic grouping variables

WarmingBurning

With a mean of 55.41 (St. Dev. 28.875) and a median of 58.0 fire was observed as slightly more warming than burning by the UK cohort. The distribution nominally conforms to what would be expected from a normal distribution with the exception of a prominent mode which exists between 60-70 (Fig. 6.8), demonstrating that many respondents classified fire as '*both warming and burning but slightly more burning'*. However despite this large mode being slightly on the side of burning, more respondents consider fire as warming than burning. Female respondents are mainly responsible for the largest mode (Fig. 6.9), suggesting that UK females are slightly more wary of fire than males; however this relationship was not found to be significant (χ^2 = 0.194, p = 0.660 [see Table 6.6]). In fact after analysis of the UK cohort no significant relationships were observed (Table 6.6). The lowest calculated p value was 0.068, obtained when testing for the breadth of fire-use history (χ^2 =5.385).

Figure 6.8: A histogram of the frequency of responses from the UK cohort to WarmingBurning (rev)

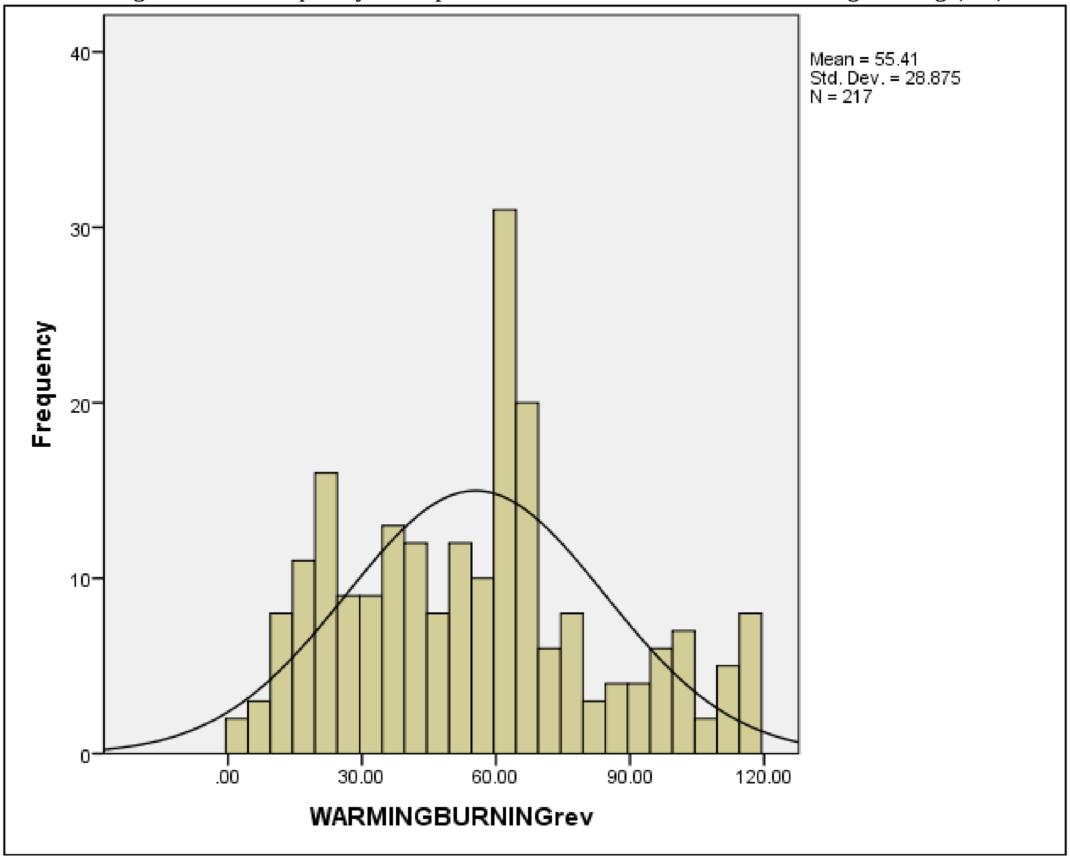
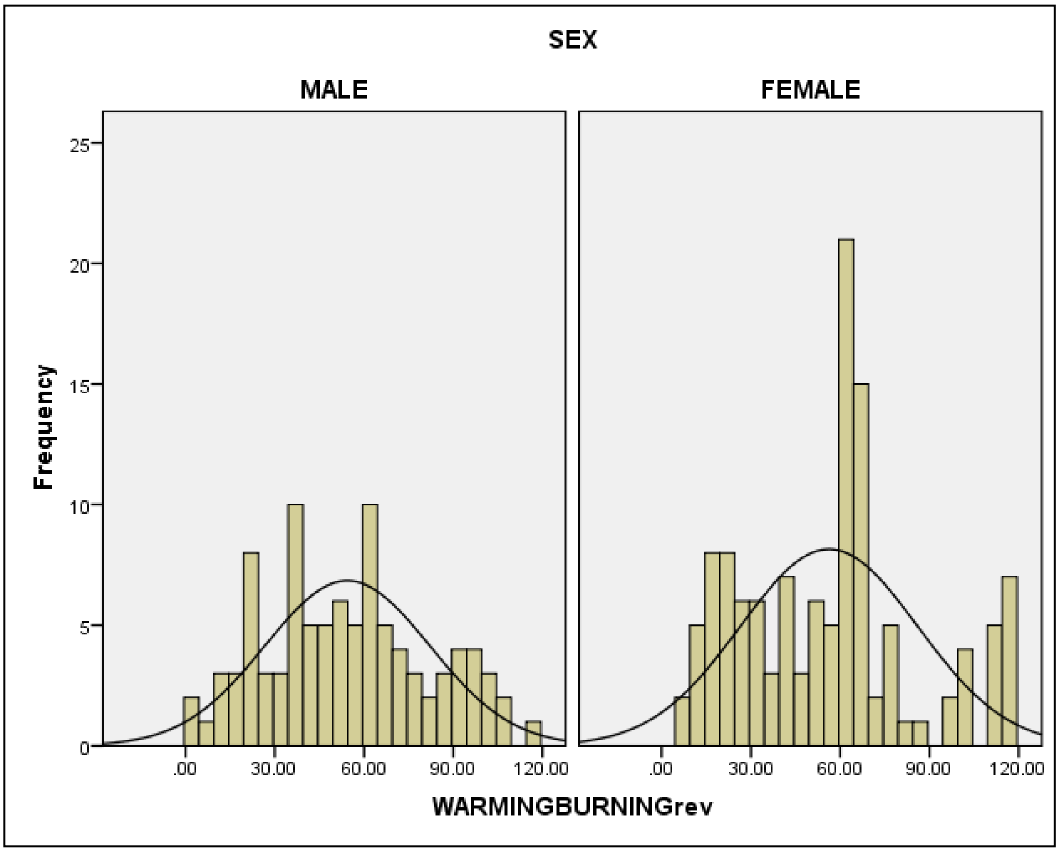


Figure 6.9: A histogram of the frequency of responses from the UK cohort to WarmingBurning (rev) filtered for sex



	SEX	N	Mean Rank		
Warmingburningrev	MALE	95	106.87	Chi-Square	0.194
	FEMALE	122	110.66	df	1
	Total	217		Asymp. Sig.	0.660
	BURNTORNOT	N	Mean Rank		
Warmingburningrev	no	118	111.63	Chi-Square	0.453
	yes	99	105.87	df	1
	Total	217		Asymp. Sig.	0.501
	PARENTHOOD	N	Mean Rank		
Warmingburningrev	NO	104	106.22	Chi-Square	0.391
	YES	113	111.56	df	1
	Total	217		Asymp. Sig.	0.532
	NewAge	N	Mean Rank		
Warmingburningrev	18-24	47	109.03		
	25-34	40	101.49	Chi-Square	2.255
	35-44	36	107.26	df	5
	45-54	28	101.61	Asymp. Sig.	0.813
	55-64	37	116.57		
	65+	29	118.95		
	Total	217			
	Smokingstatus	N	Mean Rank		
Warmingburningrev	never smoked	117	105.25	Chi-Square	1.399
	ex-smoker	77	110.97	df	2
	current smoker	23	121.46	Asymp. Sig.	0.497
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
Warmingburningrev	RURAL	62	119.12	Chi-Square	2.257
	URBAN	155	104.95	df	1
	Total	217		Asymp. Sig.	0.133
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
Warmingburningrev	RURAL	60	113.03	Chi-Square	0.342
	URBAN	157	107.46	df	1
	Total	217		Asymp. Sig.	0.558
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
Warmingburningrev	RURAL	49	106.98	Chi-Square	0.66
	URBAN	168	109.59	df	1
	Total	217		Asymp. Sig.	0.798
	FireUseCatNEW	N	Mean Rank		
Warmingburningrev	Low Usage (1-3)	44	125.63	Chi-Square	5.385
	Medium Usage (4-6)	118	108.78	df	2
	High Usage (7-10)	55	96.17	Asymp. Sig.	0.068

Table 6.6: Kruskal-Wallis test data with WarmingBurning (rev) as the test variable and a number of grouping variables

SocialViolentrev

The UK cohort mean is 59.41 (St. Dev. 29.218) and the median was 60.0. Results were multi-modal, with a very prominent sharp peak in the range 60-65 (people who consider themselves have balanced views, or very slightly in favour of violent) (Fig. 6.10). The general conclusion is that the UK cohort frame fire as being both social and violent, the absence of distinct ‘end-spectrum modes’ supports this view.

Kruskal Wallis tests calculated three different statistically significant relationships (Sex: χ^2 = 4.149, p = 0.042 [Figs. 6.11 and 6.12]; NewAge: χ^2 = 15.831, p = 0.007 [Fig. 6.12]; and FireUseCatNEW: χ^2 = 6.727, p = 0.035 [Fig. 6.13]) (Table 6.7). Male responses are more normally distributed than female responses (Fig. 6.11). When sex differences are further broken down by the age of each respondent clear trends become visible (Fig. 6.12). Within the youngest age group (18-24) females observed fire to be much more violent and less social than those from age groups 25-34/35-44/45-54; this trend is also visible in the male UK cohort but to a lesser extent. Very few people of either sex from the 45-54 age group reported fire to be more violent than social. However within the age group 55-65 this trend starts to reverse with respondents reporting that fire was more violent and less social than the three preceding age groups. Within the 65+ age group both males and females identified fire as more violent than social; a large mode of females reported fire as much more violent than social (100-120 range) (Fig. 6.12).

Within the UK cohort a significant relationship exists between the breadth of a respondent’s fire experience and whether they find fire to be social or violent. A broader experience of fire is correlated with fire being perceived as more social rather than violent (Fig. 6.13). Those with narrow fire experience reported fire to be much more violent than those with broader fire experience. Those with a medium breadth of fire experience (N=115) had the most normal distribution (Fig. 6.13) with the exception of a prominent mode in the 60-65 range; this helps explain the nature of patterns discernible in Fig. 6.10.

Figure 6.10: A histogram of the frequency of responses from the UK cohort to SocialViolent (rev)

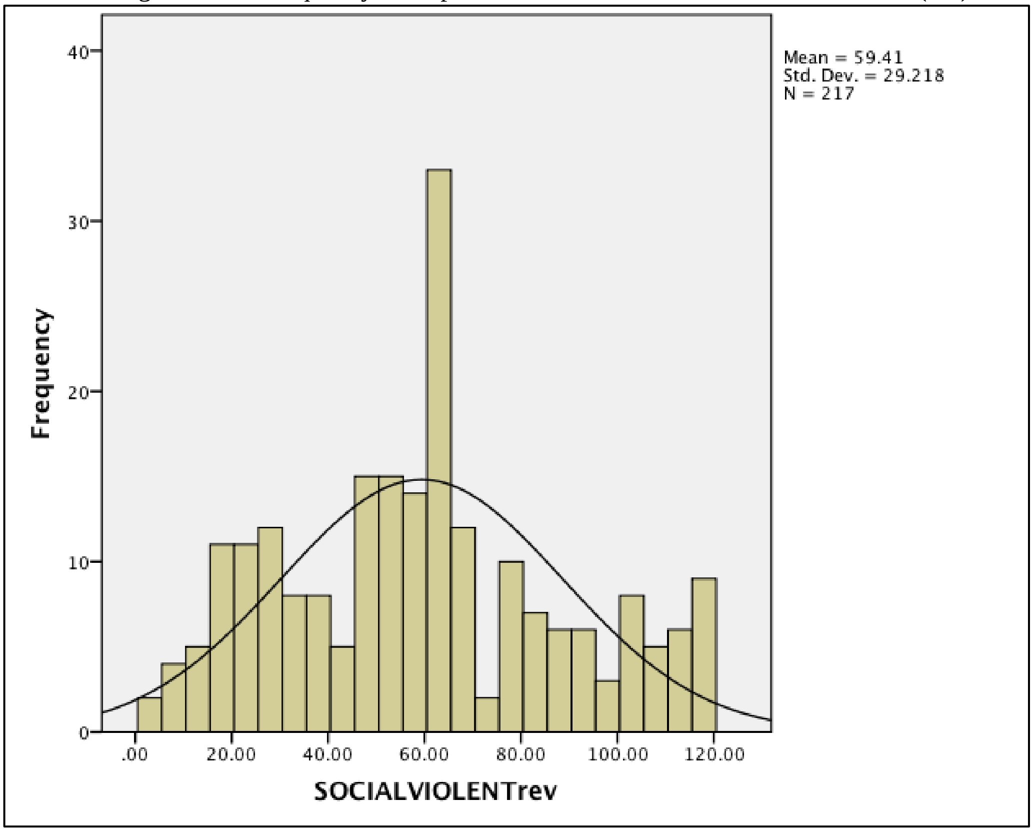


Figure 6.11: A histogram of the frequency of responses from the UK cohort to SocialViolent (rev) filtered for sex

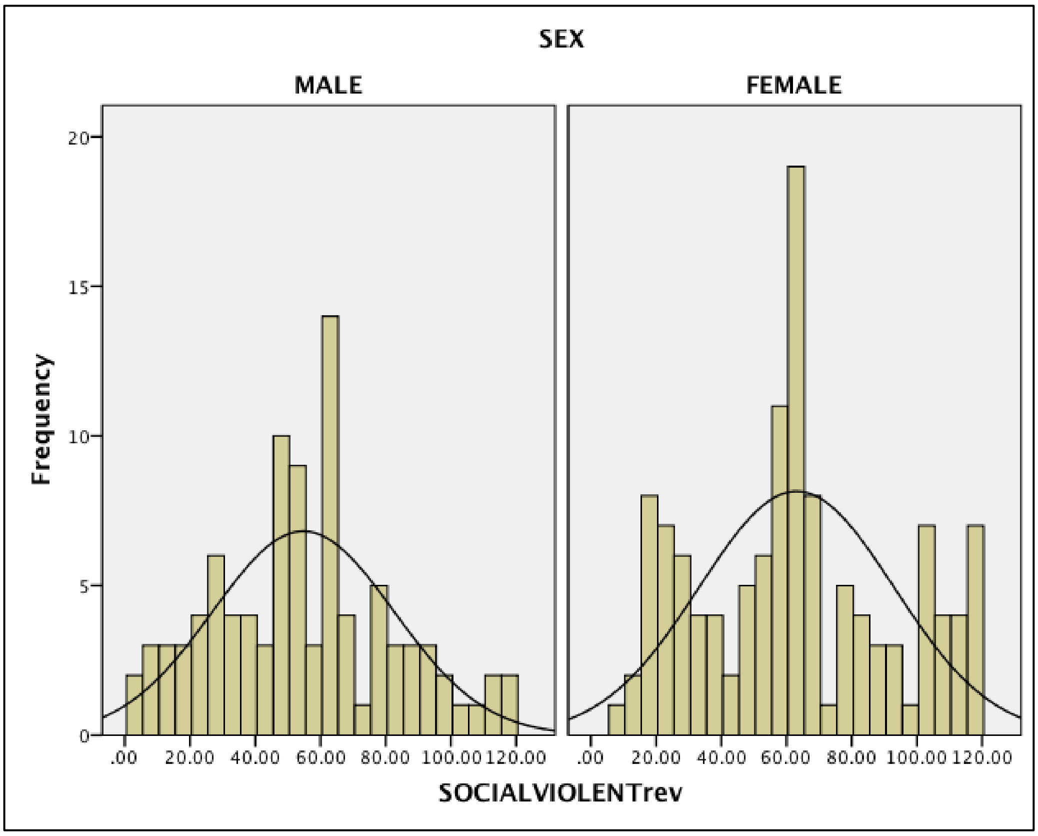


Figure 6.12: A histogram of the frequency of responses from the UK cohort to SocialViolent (rev) filtered for: i) sex; and ii) Age

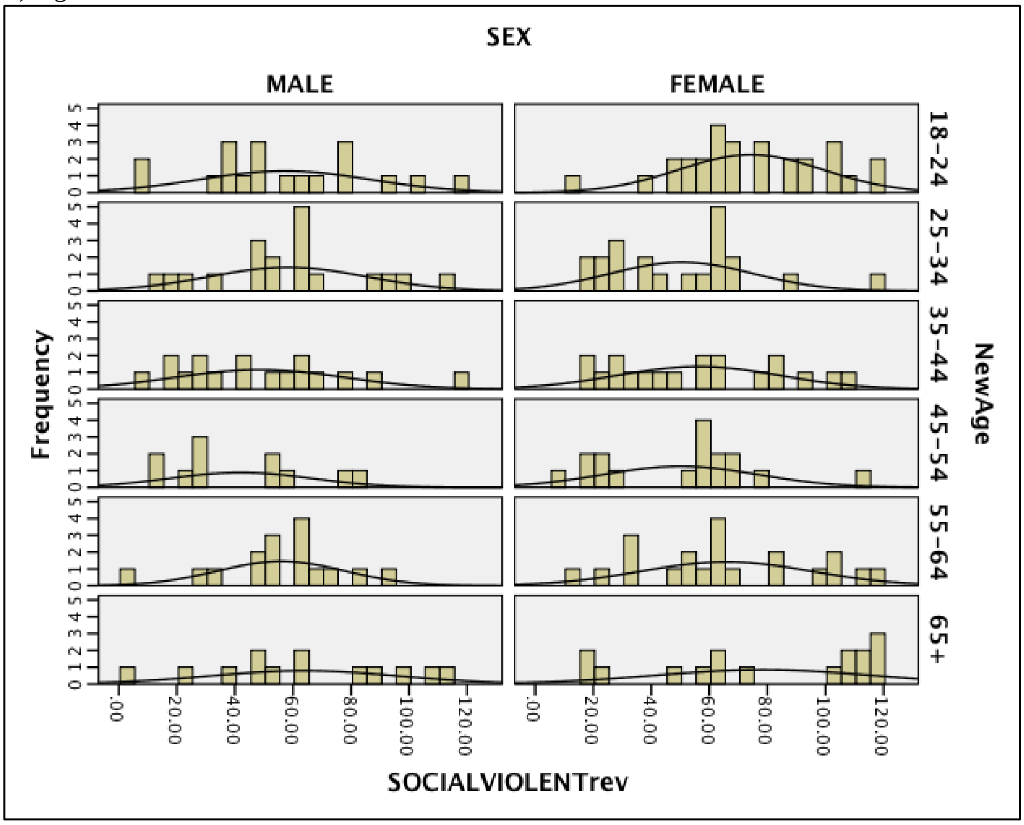
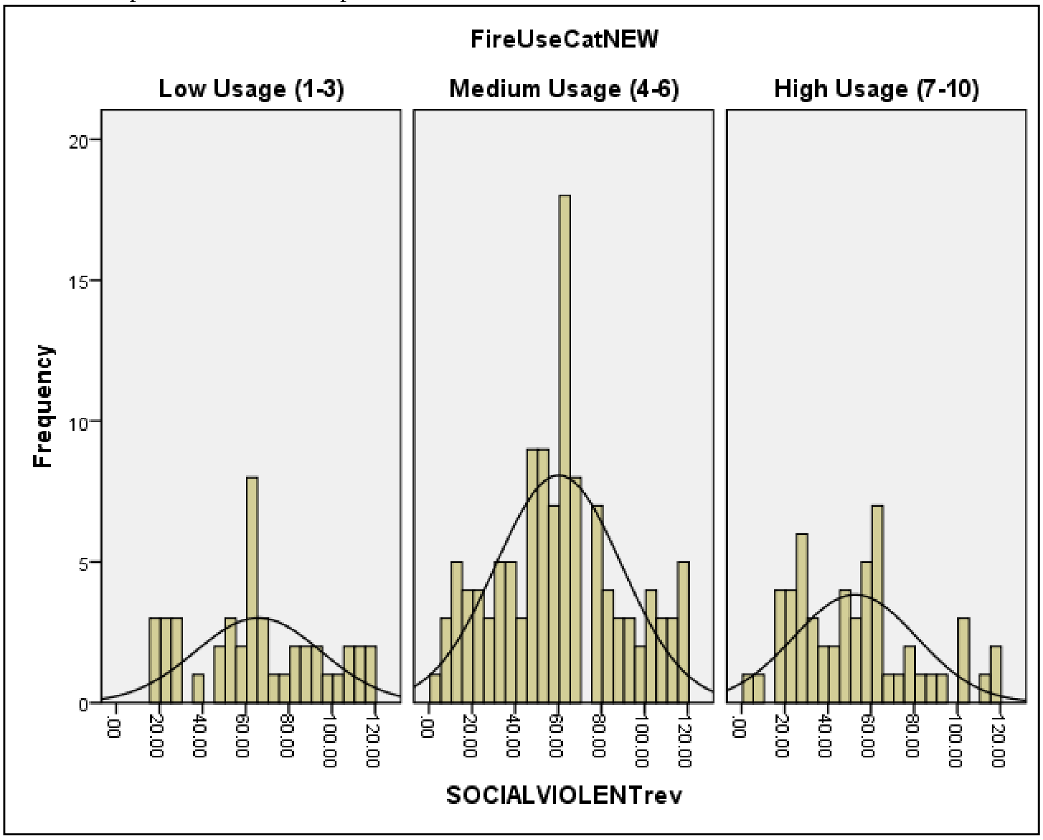


Figure 6.13: A histogram of the frequency of responses from the UK cohort to SocialViolent (rev) filtered for the breadth of their personal fire-use experience



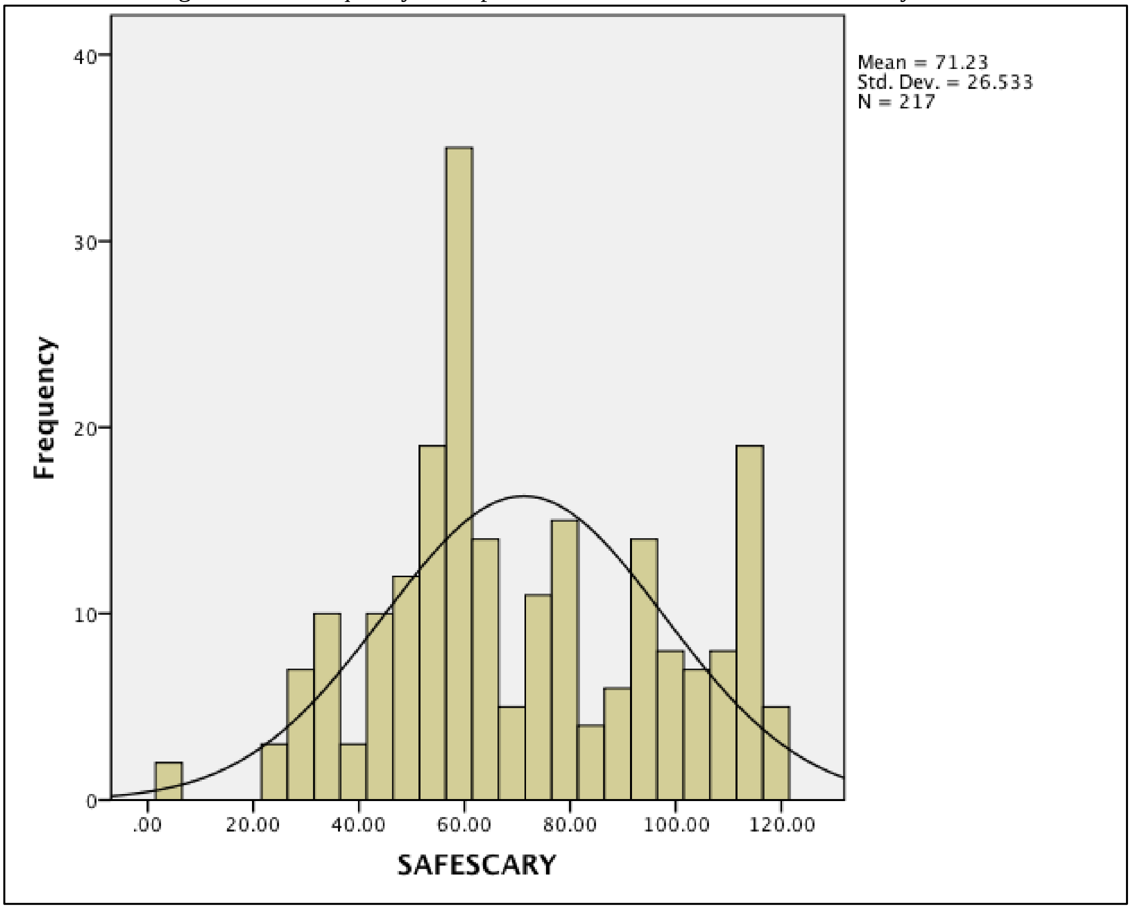
	SEX	N	Mean Rank		
SocialViolentrev	MALE	95	99.16	Chi-Square	4.149
	FEMALE	122	116.66	Df	1
	Total	217		Asymp. Sig.	0.042
	BURNTORNOT	N	Mean Rank		
SocialViolentrev	No	118	111.56	Chi-Square	0.430
	Yes	99	105.95	Df	1
	Total	217		Asymp. Sig.	0.512
	PARENTHOOD	N	Mean Rank		
SocialViolentrev	NO	104	113.19	Chi-Square	0.891
	YES	113	105.14	Df	1
	Total	217		Asymp. Sig.	0.345
	NewAge	N	Mean Rank		
SocialViolentrev	18-24	47	126.89		
	25-34	40	98.48	Chi-Square	15.831
	35-44	36	93.39	Df	5
	45-54	28	82.95	Asymp. Sig.	0.007
	55-64	37	115.65		
	65+	29	130.57		
	Total	217			
	Smokingstatus	N	Mean Rank		
SocialViolentrev	never smoked	117	107.26	Chi-Square	2.853
	ex-smoker	77	105.44	Df	2
	current smoker	23	129.76	Asymp. Sig.	0.240
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
SocialViolentrev	RURAL	62	111.85	Chi-Square	0.180
	URBAN	155	107.86	df	1
	Total	217		Asymp. Sig.	0.672
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
SocialViolentrev	RURAL	60	107.01	Chi-Square	0.083
	URBAN	157	109.76	df	1
	Total	217		Asymp. Sig.	0.773
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
SocialViolentrev	RURAL	49	110.69	Chi-Square	0.046
	URBAN	168	108.51	df	1
	Total	217		Asymp. Sig.	0.830
	FireUseCatNEW	N	Mean Rank		
SocialViolentrev	Low Usage (1-3)	44	124.56	Chi-Square	6.727
	Medium Usage (4-6)	118	111.00	df	2
	High Usage (7-10)	55	92.27	Asymp. Sig.	0.035

Table 6.7: Kruskal-Wallis test data with SocialViolent (rev) as the test variable and a number of demographic grouping variables

SafeScary

For the UK cohort the mean was 71.23 (St.Dev. 26.533) and the median was 64.0; both of which suggest that the UK cohort frame fire as, on balance, more scary than safe. A large mode outside of what would be expected from a normal distribution clusters around the 50-60 range (people who found fire to be slightly more safe than scary or people who found fire to be equally safe and scary). Another prominent mode is in the range 105-120 (Fig. 6.14) which corresponds to a small population of people who reported that they find fire to be much more scary than safe. They, coupled with the fact that only a very small number of people thought the opposite (range of 0-20), are responsible for the large disparity between the mean and median values.

Figure 6.14: A histogram of the frequency of responses from the UK cohort to SafeScary



A number of statistically significant relationships are observable (Table 6.8) (BurntOrNot: $\chi^2 = 8.610$, p = 0.003 [Fig. 6.15]; Parenthood: $\chi^2 = 4.991$, p = 0.025 [Fig. 6.15]; and NewAge: $\chi^2 = 12.239$, p = 0.032 [Fig. 6.16]). Sex and the breadth of a respondent's fire experience were also found to be significant to the 90% confidence level but not the 95% confidence level (Table 6.8)

Figure 6.15: A histogram of the frequency of responses from the UK cohort to SafeScary filtered for: i) whether people have been previously burnt or not; and ii) whether they have produced offspring

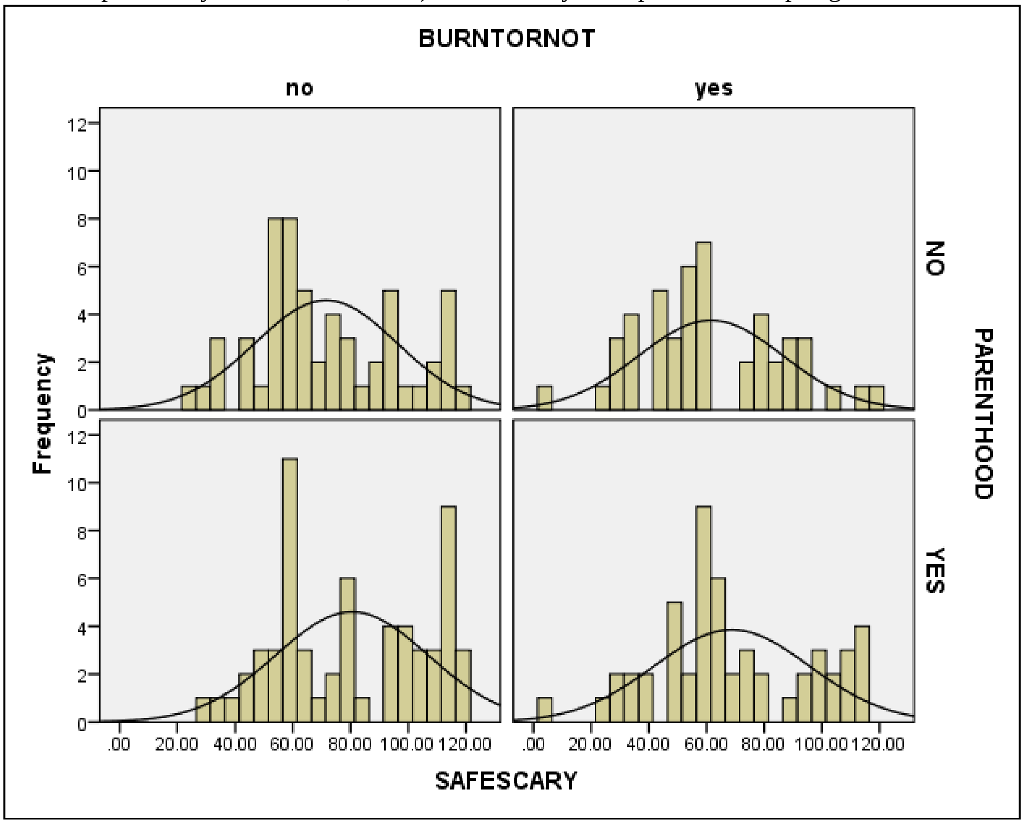
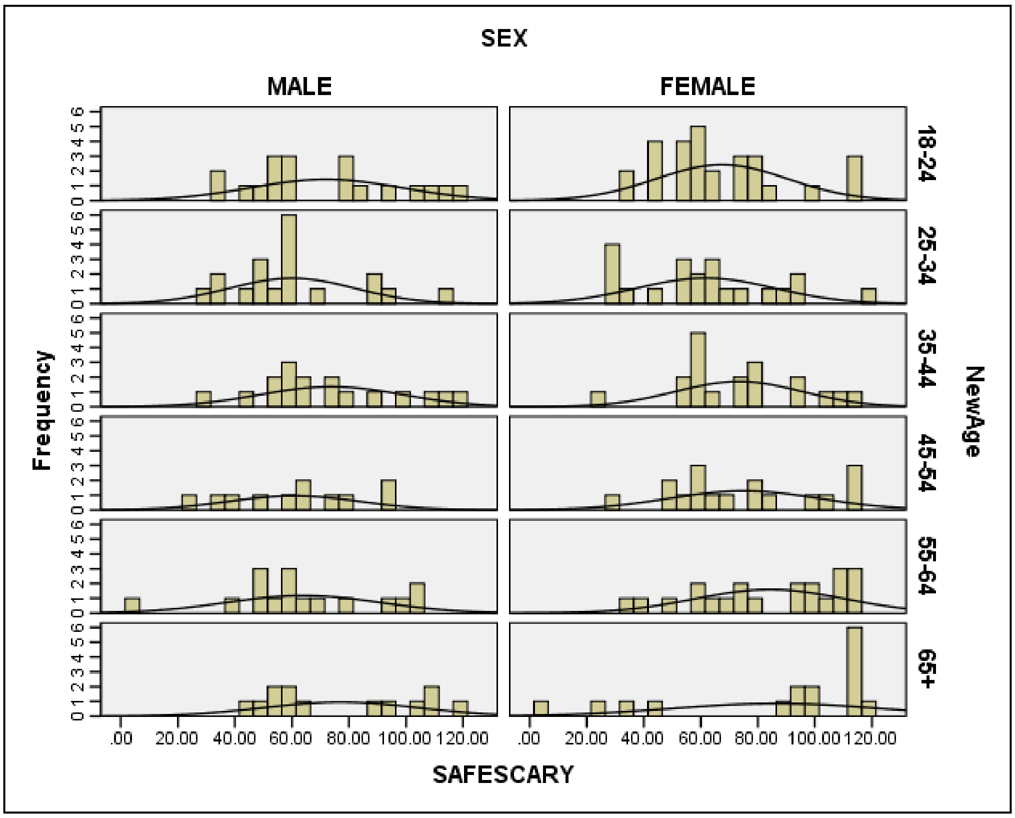


Figure 6.16: A histogram of the frequency of responses from the UK cohort to SafeScary filtered for: i) sex; and ii) age



	SEX	N	Mean Rank		
SafeScary	MALE	95	100.99	Chi-Square	2.748
	FEMALE	122	115.23	df	1
	Total	217		Asymp. Sig.	0.097
	BURNTORNOT	N	Mean Rank		
SafeScary	no	118	120.45	Chi-Square	8.610
	yes	99	95.35	df	1
	Total	217		Asymp. Sig.	0.003
	PARENTHOOD	N	Mean Rank		
SafeScary	NO	104	99.08	Chi-Square	4.991
	YES	113	118.13	df	1
	Total	217		Asymp. Sig.	0.025
	NewAge	N	Mean Rank		
SafeScary	18-24	47	103.87		
	25-34	40	84.09	Chi-Square	12.239
	35-44	36	117.06	df	5
	45-54	28	105.54	Asymp. Sig.	0.032
	55-64	37	118.89		
	65+	29	132.40		
	Total	217			
	Smokingstatus	N	Mean Rank		
SafeScary	never smoked	117	109.29	Chi-Square	0.033
	ex-smoker	77	109.23	df	2
	current smoker	23	106.74	Asymp. Sig.	0.983
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
SafeScary	RURAL	62	100.93	Chi-Square	1.435
	URBAN	155	112.23	df	1
	Total	217		Asymp. Sig.	0.231
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
SafeScary	RURAL	60	101.48	Chi-Square	1.192
	URBAN	157	111.88	df	1
	Total	217		Asymp. Sig.	0.275
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
SafeScary	RURAL	49	108.35	Chi-Square	0.007
	URBAN	168	109.19	df	1
	Total	217		Asymp. Sig.	0.934
	FireUseCatNEW	N	Mean Rank		
SafeScary	Low Usage (1-3)	44	125.31	Chi-Square	5.781
	Medium Usage (4-6)	118	109.53	df	2
	High Usage (7-10)	55	94.83	Asymp. Sig.	0.056

Table 6.8: Kruskal-Wallis test data with SafeScary as the test variable and a number of grouping variables

Fig.6.15 plots two significant variables against each other; parenthood and whether a respondent has been previously burnt. Respondents who had been burnt found fire to be significantly less scary and safer than those who reported that they had never been burnt. Likewise those who had not produced children found fire to be significantly less scary and safer than those who were parents; however as age was also found to be significant this could equally be an artifact of sampling biases, (the UK cohort included many university students) manifesting in an number of different ways.

A number of interesting trends are observable within the data presented in Fig. 6.15. There were many more people who classified fire as more safe than scary (<60) within the population of people ‘who had been burnt but were not parents’ than would be expected from a normal distribution. The only people who responded as viewing fire as very safe and not scary (0-20 range) also responded as having previously being burnt. Two distinct modes are visible within the data of people with children; the first in the 55-65 range (think fire is both equally safe and scary) and in the 110-120 range (think fire is very scary and not very safe). These modes are smaller but still visible within the ‘not burnt/no children’ cohort but are almost imperceptive in the ‘burnt but no children’ cohort.

When it comes to analysing the age related data (Fig.6.16) a number of interesting trends are apparent. Firstly across all age groups a large proportion of men find fire to be more safe than scary. Older women are largely responsible for the mode observed in Fig. 6.14 who reported fire to be very scary and not safe at all (110-120 range). Out of all the women, those between the ages of 25-34 find fire to be least scary.

UsefulHazardousrev

Data shows that the UK cohort perceives fire as being on the whole slightly more useful than hazardous (Fig 6.17). Responses from participants who considered fire ‘more useful than hazardous’ (0-60 range) appear ‘more normally distributed’ than those who consider ‘fire more hazardous than useful’ (Fig 6.17). The largest mode is in the 50-70 range (people who are roughly balanced in their views) however very few people responded in the 70-90 range resulting in the mean of 55.37 (St. Dev. 28.328) being a little lower than the median (58.0).

	SEX	N	Mean Rank		
UsefulHazardousrev	MALE	95	96.47	Chi-Square	6.736
	FEMALE	122	118.76	df	1
	Total	217		Asymp. Sig.	0.009
	BURNTORNOT	N	Mean Rank		
UsefulHazardousrev	no	118	114.33	Chi-Square	1.862
	yes	99	102.65	df	1
	Total	217		Asymp. Sig.	0.172
	PARENTHOOD	N	Mean Rank		
UsefulHazardousrev	NO	104	103.94	Chi-Square	1.299
	YES	113	113.66	df	1
	Total	217		Asymp. Sig.	0.254
	NewAge	N	Mean Rank		
UsefulHazardousrev	18-24	47	103.74		
	25-34	40	101.48	Chi-Square	3.728
	35-44	36	108.10	df	5
	45-54	28	101.54	Asymp. Sig.	0.589
	55-64	37	119.92		
	65+	29	122.29		
	Total	217			
	Smokingstatus	N	Mean Rank		
UsefulHazardousrev	never smoked	117	109.20	Chi-Square	0.290
	ex-smoker	77	110.60	df	2
	current smoker	23	102.61	Asymp. Sig.	0.865
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
UsefulHazardousrev	RURAL	62	106.77	Chi-Square	0.109
	URBAN	155	109.89	df	1
	Total	217		Asymp. Sig.	0.741
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
UsefulHazardousrev	RURAL	60	108.22	Chi-Square	0.013
	URBAN	157	109.30	df	1
	Total	217		Asymp. Sig.	0.910
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
UsefulHazardousrev	RURAL	49	105.56	Chi-Square	0.190
	URBAN	168	110.00	df	1
	Total	217		Asymp. Sig.	0.663
	FireUseCatNEW	N	Mean Rank		
UsefulHazardousrev	Low Usage (1-3)	44	136.57	Chi-Square	17.527
	Medium Usage (4-6)	118	110.53	df	2
	High Usage (7-10)	55	83.65	Asymp. Sig.	<0.001

Table 6.9: Kruskal-Wallis test data with HazardousUseful (rev) as the test variable and a number of demographic grouping variables

Two statistically significant relationships were observed using Kruskal-Wallis testing (Table. 6.9); sex (χ^2 = 6.736, p = 0.009) (Figs. 6.18 and 6.20) and FireUseCategoryNew (χ^2 = 17.527, p = <0.001) (Figs. 6.19 and 6.20). Males were much more likely to find fire-useful than females (Fig 6.18); additionally no male respondents answered within the 70-80 range. While a visible mode exists within the male data in the 55-70 range it is far more prominent within the female cohort. A smaller but very prominent mode exists within the female data in the 15-20 range (Fig 6.18). Fig. 6.20 shows that this mode is almost entirely made of respondents who had a medium or high breadth of experience of fire; modes which are very prominently outside the parameters of a normal distribution.

Very few people with a high breadth of experience of fire stated that they found fire to be more hazardous than useful (Figs. 6.19 and 6.20). Fig. 6.19 shows the strength of the relationship between the breadth of experience of fire and whether respondents from the UK cohort view fire as being useful or hazardous; the broader a respondents experience of fire then the more useful and the less hazardous it is viewed. Whether people had been previously burnt or not was not found to be statistically significant (χ^2 = 1.862, p = 0.172) (Table 6.9).

Figure 6.17: A histogram of the frequency of responses from the UK cohort to UsefulHazardous (rev)

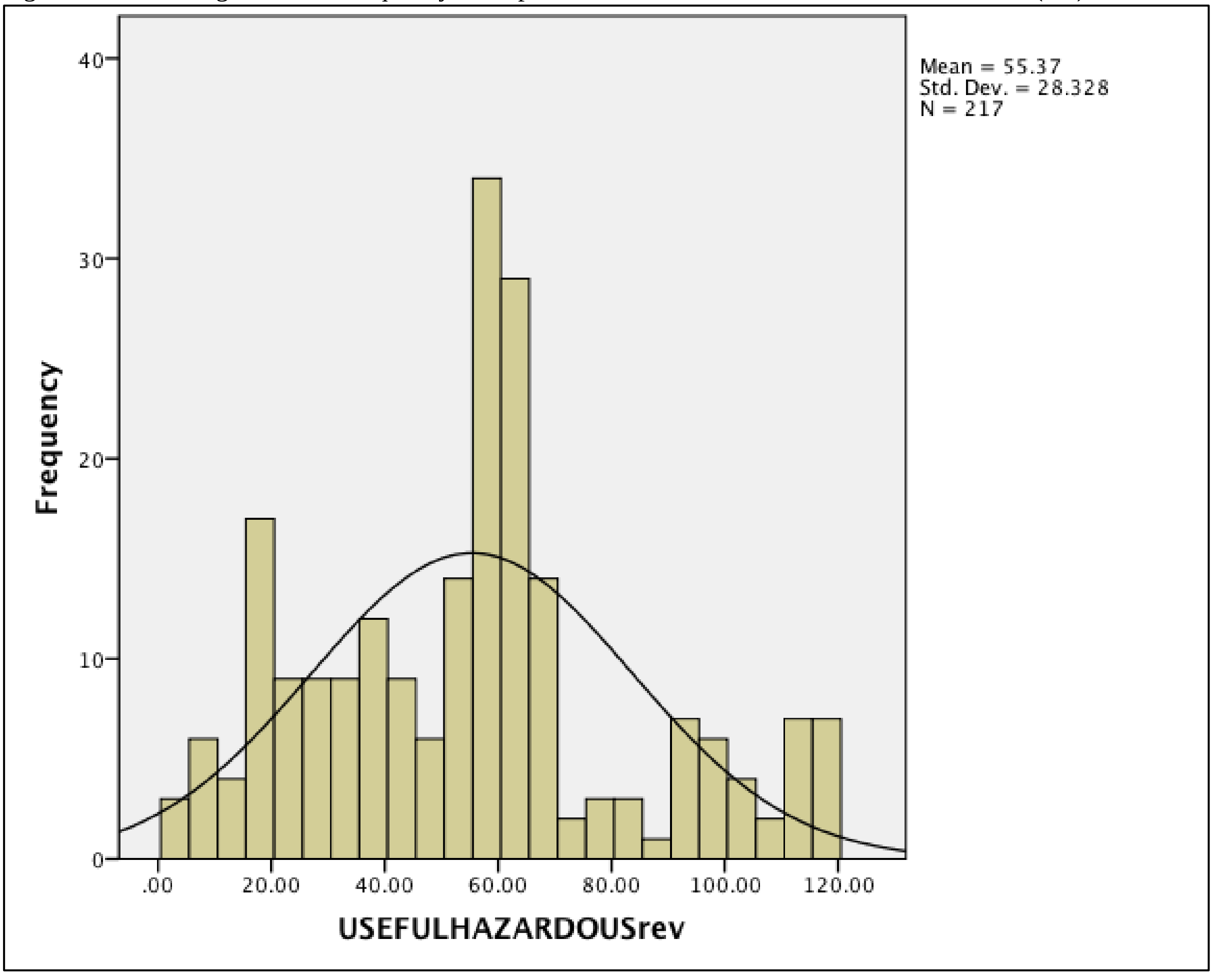


Figure 6.18: A histogram of the frequency of responses from the UK cohort to UsefulHazardous (rev) filtered by the sex of respondents

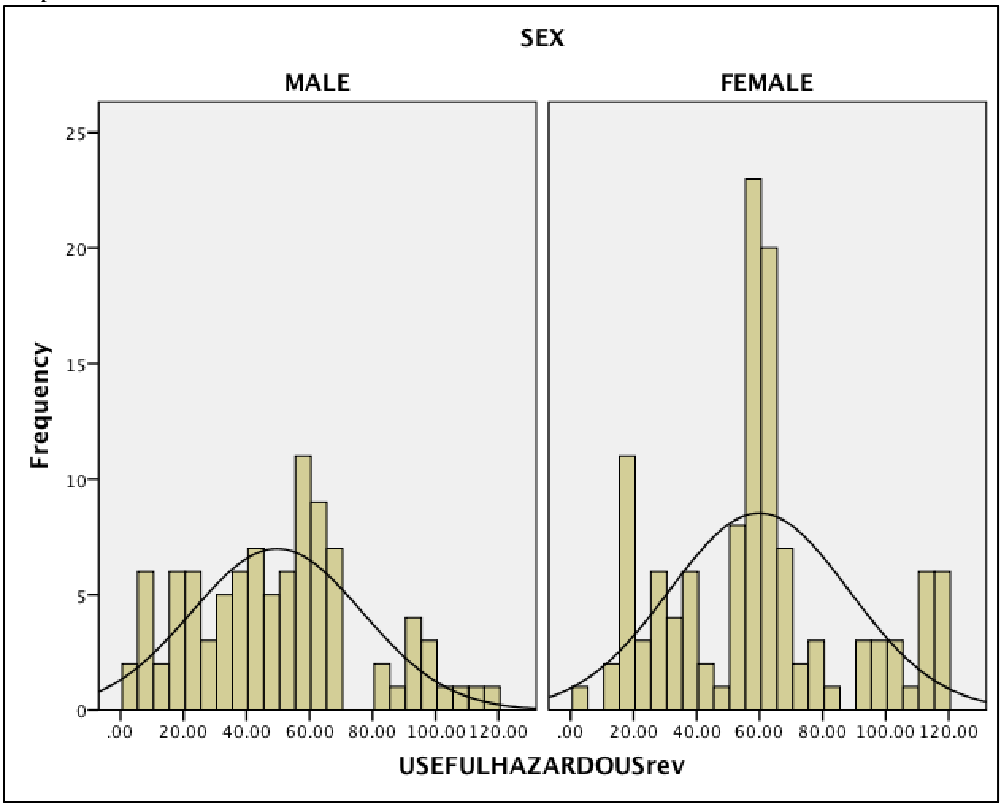


Figure 6.19: A histogram of the frequency of responses from the UK cohort to UsefulHazardous (rev) filtered by the breadth of fire-use experience

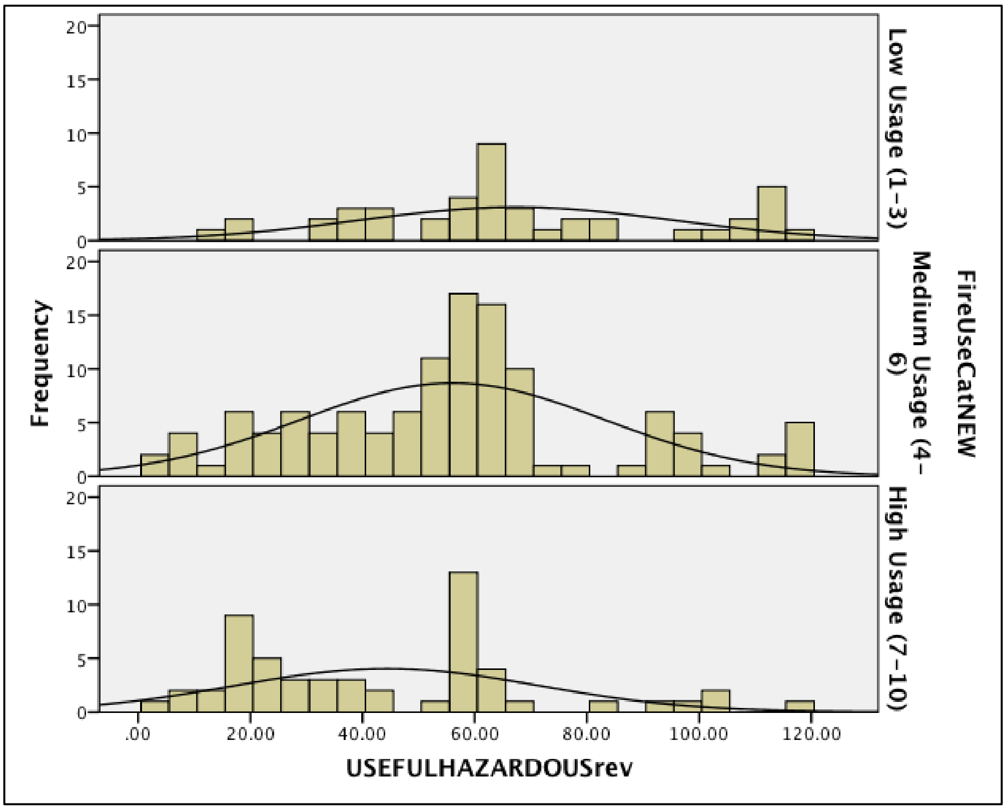
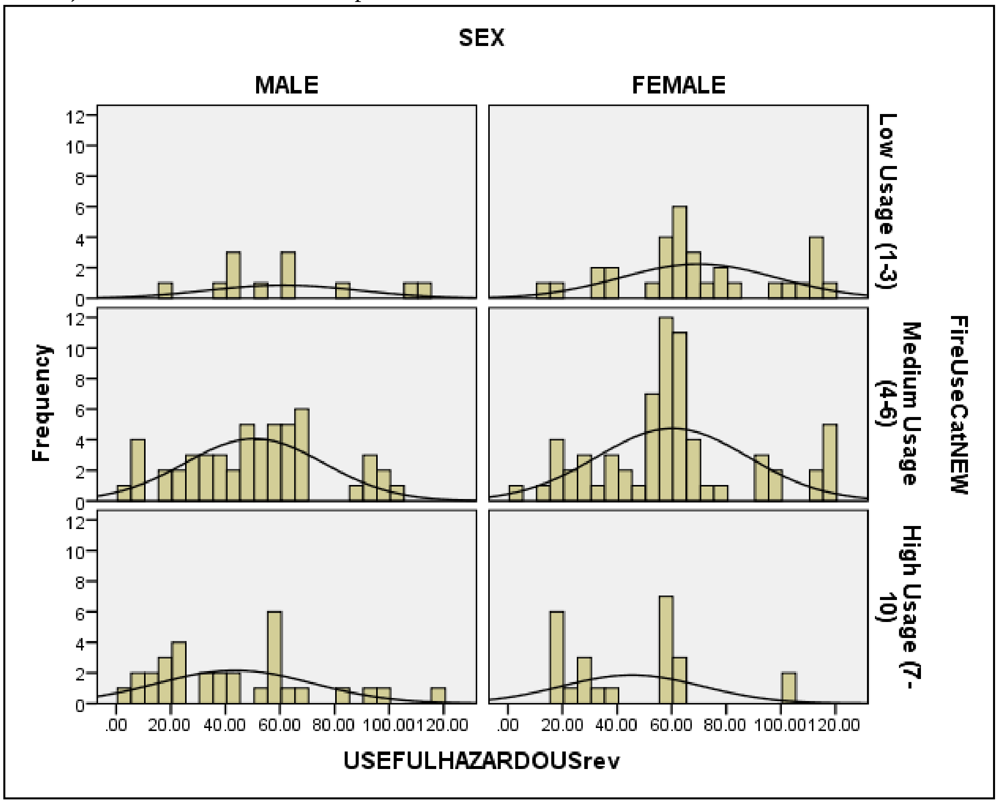


Figure 6.20: A histogram of the frequency of responses from the UK cohort to UsefulHazardous (rev) filtered by: i) sex; and ii) the breadth of fire-use experience



ComfortingStressful

The response from the UK cohort was overwhelmingly in favour of fire being comforting (Fig. 6.21) rather than stressful with a mean of 38.29 (St. Dev. 25.073) and a median of 35.0. A very large mode exists in the 0-45 range; a second smaller mode is located around the 55-65 range denoting the large number of people who reported that they felt fire was equally comforting and stressful. Kruskal-Wallis tests calculated that the only statistically significant relationship was with the breadth of fire experience (χ^2 = 6.624, p = 0.036) (Table 6.10). Fig. 6.22 clearly shows that the greater the breadth of experience with fire the greater the propensity to view fire as comforting rather than stressful. Again, whether people had been previously burnt or not was not statistically significant (χ^2 = 0.837, p = 0.360) (Table 6.10) suggesting previous negative experiences with fire did not alter the way fire is placed within an individual's LOF. The sex or age of a respondent and whether they had children also had

Figure 6.21: A histogram of the frequency of responses from the UK cohort to ComfortingStressful

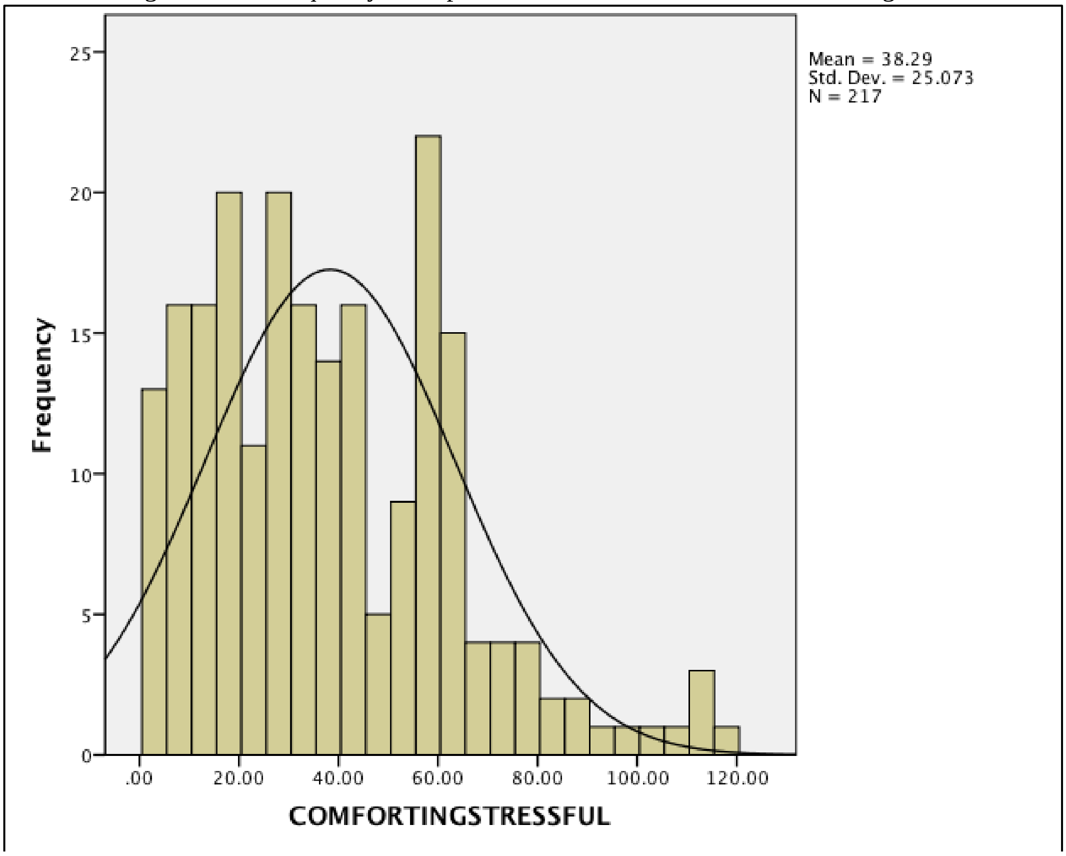
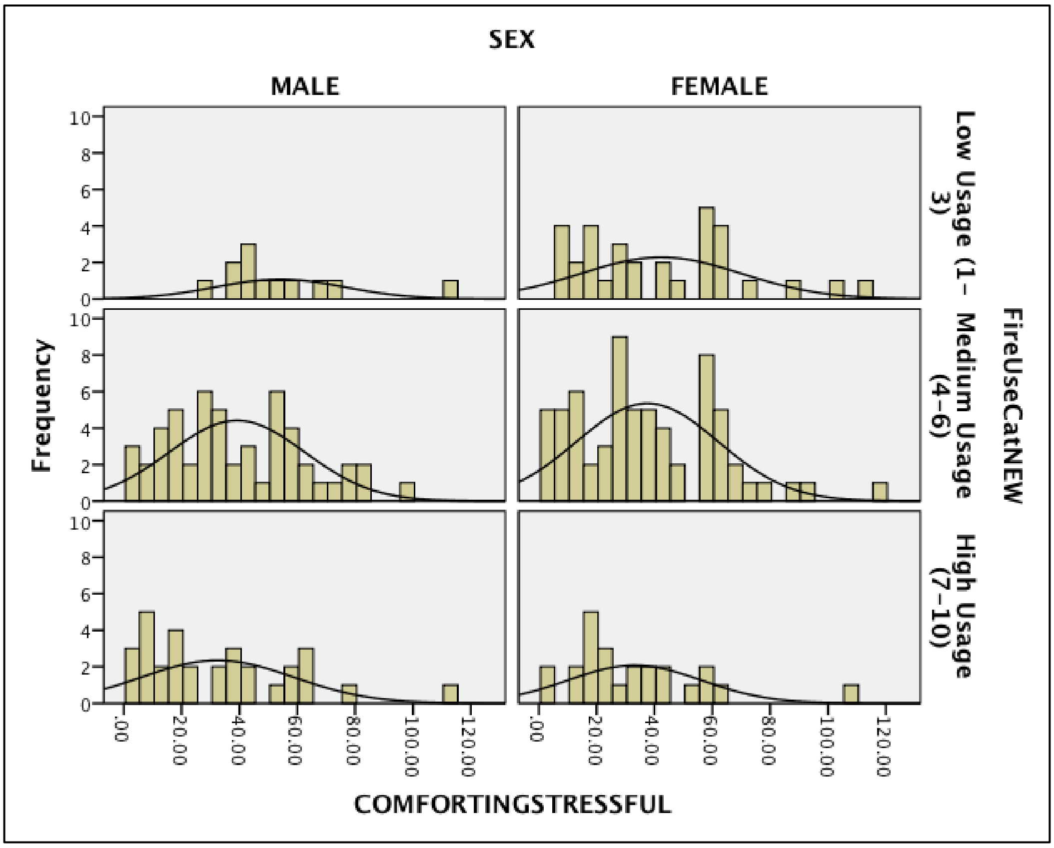


Figure 6.22: A histogram of the frequency of responses from the UK cohort to ComfortingStressful filtered by: i) sex; and, ii) the breadth of fire experience



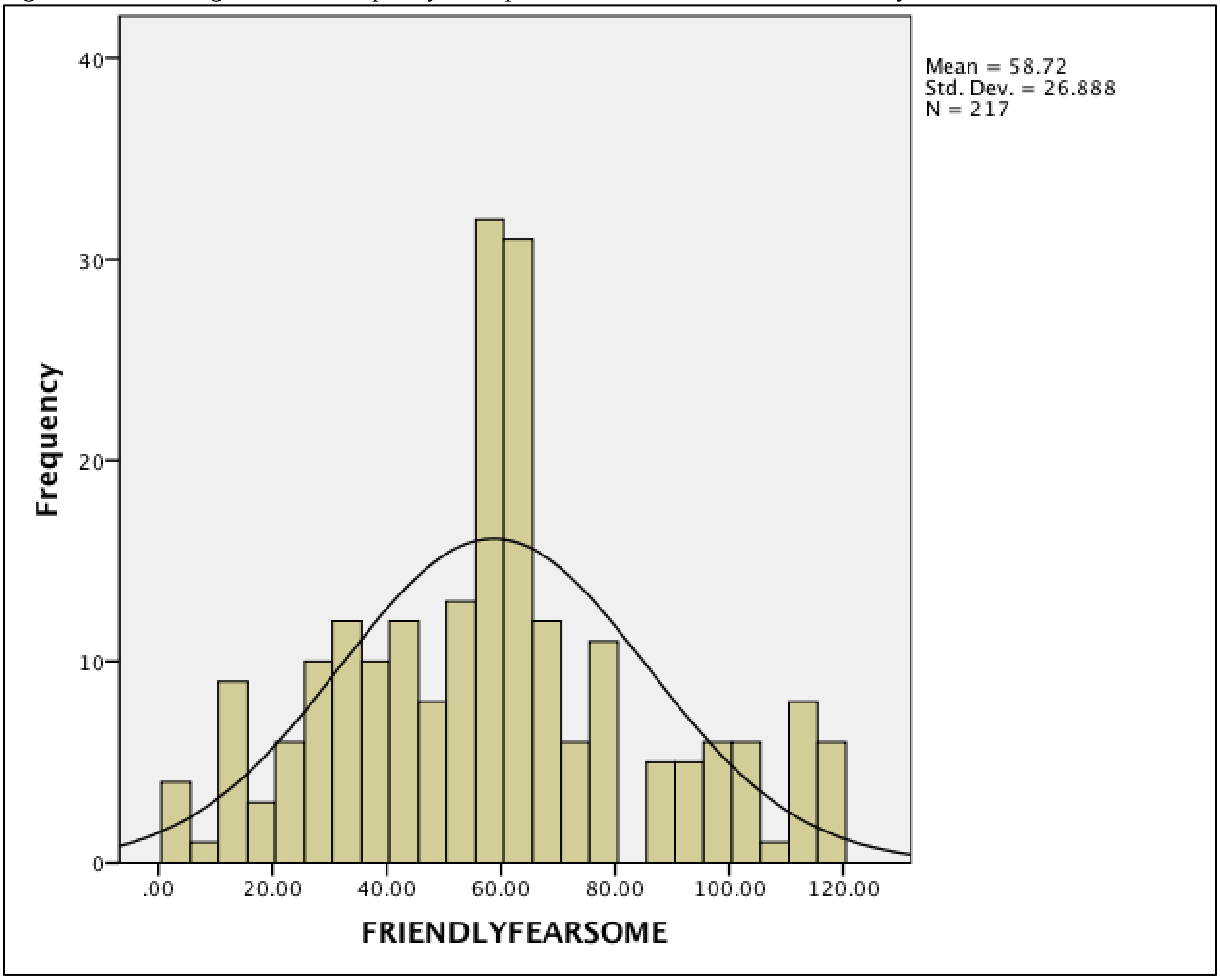
no statistically significant impact on how people responded to this question within the UK cohort. Fig. 6.22 shows that only 5 males and 7 females responded within the 80-120 range (find fire highly stressful and barely comforting, if at all) strongly supporting the overall conclusion that the UK cohort found fire much more comforting than stressful.

	SEX	N	Mean Rank		
ComfortingStressful	MALE	95	110.61	Chi-Square	0.111
	FEMALE	122	107.75	Df	1
	Total	217		Asymp. Sig.	0.739
	BURNTORNOT	N	Mean Rank		
ComfortingStressful	no	118	112.57	Chi-Square	0.837
	yes	99	104.74	Df	1
	Total	217		Asymp. Sig.	0.360
	PARENTHOOD	N	Mean Rank		
ComfortingStressful	NO	104	114.15	Chi-Square	1.346
	YES	113	104.26	Df	1
	Total	217		Asymp. Sig.	0.246
	NewAge	N	Mean Rank		
ComfortingStressful	18-24	47	117.52		
	25-34	40	103.14	Chi-Square	6.487
	35-44	36	125.97	Df	5
	45-54	28	93.66	Asymp. Sig.	0.262
	55-64	37	108.59		
	65+	29	97.53		
	Total	217			
	Smokingstatus	N	Mean Rank		
ComfortingStressful	never smoked	117	107.01	Chi-Square	0.267
	ex-smoker	77	110.97	Df	2
	current smoker	23	112.54	Asymp. Sig.	0.875
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
ComfortingStressful	RURAL	62	119.11	Chi-Square	2.253
	URBAN	155	104.95	Df	1
	Total	217		Asymp. Sig.	0.133
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
ComfortingStressful	RURAL	60	110.36	Chi-Square	0.39
	URBAN	157	108.48	Df	1
	Total	217		Asymp. Sig.	0.844
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
ComfortingStressful	RURAL	49	95.24	Chi-Square	3.039
	URBAN	168	113.01	Df	1
	Total	217		Asymp. Sig.	0.081
	FireUseCatNEW	N	Mean Rank		
ComfortingStressful	Low Usage (1-3)	44	126.16	Chi-Square	6.624
	Medium Usage (4-6)	118	109.79	Df	2
	High Usage (7-10)	55	93.58	Asymp. Sig.	0.036

Table 6.10: Kruskal-Wallis test data with ComfortingStressful as the test variable and a number of grouping variables

FriendlyFearsome

Figure 6.23: A histogram of the frequency of responses from the UK cohort to FriendlyFearsome



The UK cohort distribution is nominally tri-modal (Fig 6.23). Small modes lie at each end of the spectrum showing minority populations who feel very strongly that fire is fearsome or friendly, but the most prominent and large mode is in the 55-65 range denoting a large number of respondents with very balanced views visible in the statistics. The UK mean value was 58.72 (St. Dev. = 26.888) and the median was 59.0; both of which suggest that the UK cohort viewed fire as being both friendly and fearsome with a very slight inclination towards friendly. Using Kruskal-Wallis tests two statistically significant relationships were identified (Table 6.11); sex ($\chi^2 = 5.105$, p = 0.024 [Figs. 6.24 and 6.25]) and the breadth of fire-use experience ($\chi^2 = 6.449$, p = 0.040 [Fig. 6.25]).

Figure 6.24: A histogram of the frequency of responses from the UK cohort to FriendlyFearsome filtered by sex

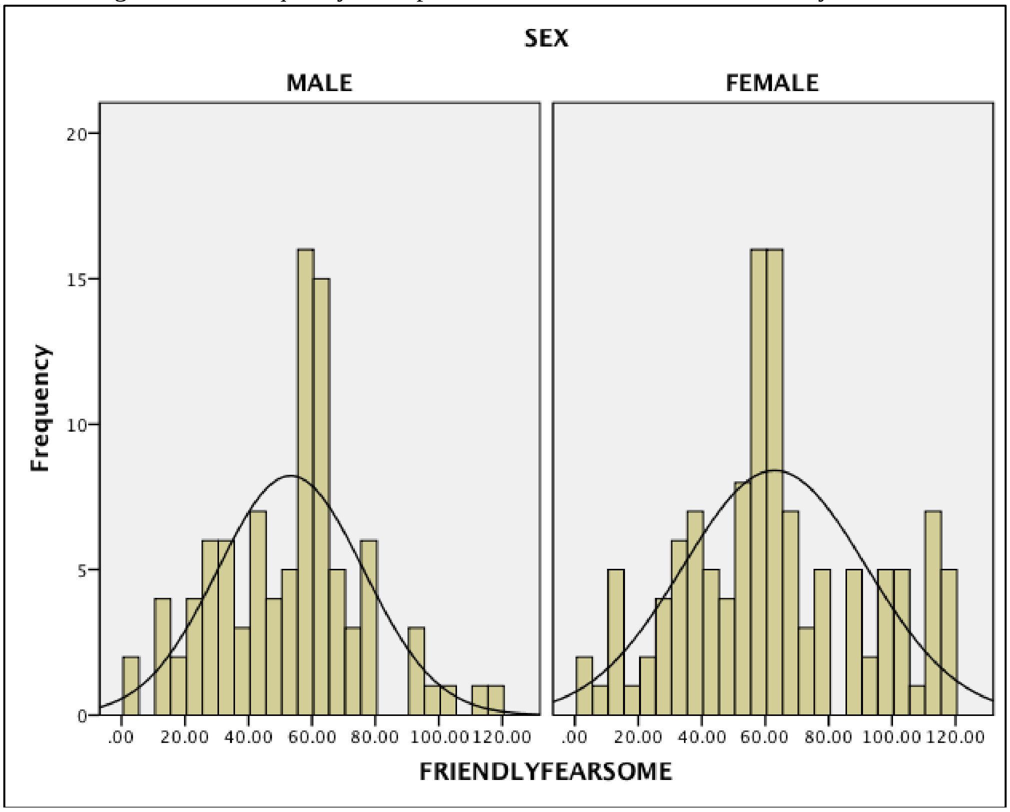
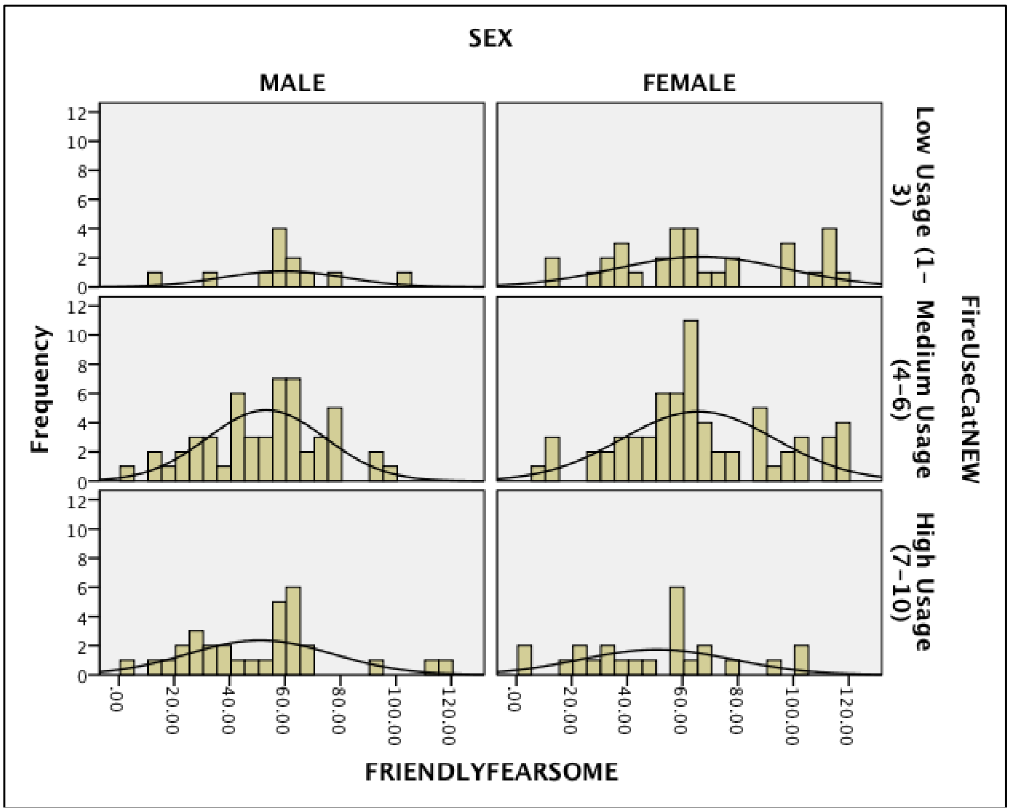


Figure 6.25: A histogram of the frequency of responses from the UK cohort to FriendlyFearsome filtered by: i) sex; and, ii) the breadth of fire experience



Males were significantly more likely to view fire as being more friendly than females (Fig 6.24). The very prominent mode identified in the 55-65 range (Fig 6.23) is made up of both Males and females; however the mode in the 110-120 range (those who find fire very fearsome and not friendly at all) can now be seen as being largely populated by female respondents (Fig. 6.24). When analysis is then made accounting for both sex and the breadth

	SEX	N	Mean Rank		
FriendlyFearsome	MALE	95	98.09	Chi-Square	5.105
	FEMALE	122	117.50	df	1
	Total	217		Asymp. Sig.	0.024
	BURNTORNOT	N	Mean Rank		
FriendlyFearsome	No	118	114.51	Chi-Square	1.995
	yes	99	102.43	df	1
	Total	217		Asymp. Sig.	0.158
	PARENTHOOD	N	Mean Rank		
FriendlyFearsome	NO	104	107.21	Chi-Square	0.163
	YES	113	110.65	df	1
	Total	217		Asymp. Sig.	0.686
	NewAge	N	Mean Rank		
FriendlyFearsome	18-24	47	111.17		
	25-34	40	96.65	Chi-Square	6.862
	35-44	36	110.67	df	5
	45-54	28	100.79	Asymp. Sig.	0.231
	55-64	37	104.65		
	65+	29	133.93		
	Total	217			
	Smokingstatus	N	Mean Rank		
FriendlyFearsome	never smoked	117	107.10	Chi-Square	1.023
	ex-smoker	77	108.18	df	2
	current smoker	23	121.43	Asymp. Sig.	0.600
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
FriendlyFearsome	RURAL	62	110.48	Chi-Square	0.048
	URBAN	155	108.41	df	1
	Total	217		Asymp. Sig.	0.827
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
FriendlyFearsome	RURAL	60	108.15	Chi-Square	0.15
	URBAN	157	109.32	df	1
	Total	217		Asymp. Sig.	0.902
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
FriendlyFearsome	RURAL	49	115.27	Chi-Square	0.631
	URBAN	168	107.17	df	1
	Total	217		Asymp. Sig.	0.427
	FireUseCatNEW	N	Mean Rank		
FriendlyFearsome	Low Usage (1-3)	44	120.38	Chi-Square	6.449
	Medium Usage (4-6)	118	113.12	df	2
	High Usage (7-10)	55	91.05	Asymp. Sig.	0.040

Table 6.11: Kruskal-Wallis test data with friendlyfearsome as the test variable and a number of demographic grouping variables

of fire experience this mode is discerned to be largely populated by females with low or medium breadth of fire-use experience (Fig 6.25). When the male population is also viewed through this double filter (Fig 6.25) the relationship between a greater propensity to view fire as friendly and the breadth of fire experience is clearly visible.

GiftThreat

Five modes are visible (Fig 6.26), but with the exception of a very prominent central mode (in the range of 55-65 - those who have very balanced views) the distribution was very balanced. This perceived balance is further supported by the fact that the mean was 60.001 (St. Dev. 27.816) and the median was 60.00. Data therefore suggests that within the Landscape of Fear of the UK cohort fire is very much seen as both a gift and a threat in equal proportions. Despite this perceived overall balance two statistically significant relationships were observed using Kruskal-Wallis tests; whether respondents had been previously burnt or not ($\chi^2 = 6.537$, $p = 0.011$) and the breadth of fire-use experience ($\chi^2 = 8.401$, $p = 0.015$).

Respondents who had previously been burnt were more likely to view fire as a gift (Fig. 6.27) as did those with broader fire-use experience (Fig 6.28). Amongst females who had previously been burnt a clear trend can be observed, with older females finding fire to be more of a gift than younger females; however when all the data from the UK cohort was analysed age was not found to have any statistical significance ($\chi^2 = 7.330$, $p = 0.197$). Interestingly, but perhaps not surprisingly, no respondent who had a low breadth of fire-use experience (N = 44) felt very strongly that fire was a gift (0-25 range) whereas about one fifth of this group felt very strongly that fire was a threat (95-120 range) (Fig. 6.28). Those with a high breadth of fire-use experience did contain a small population who viewed fire strongly

Figure 6.26: A histogram of the frequency of responses from the UK cohort to GiftThreat

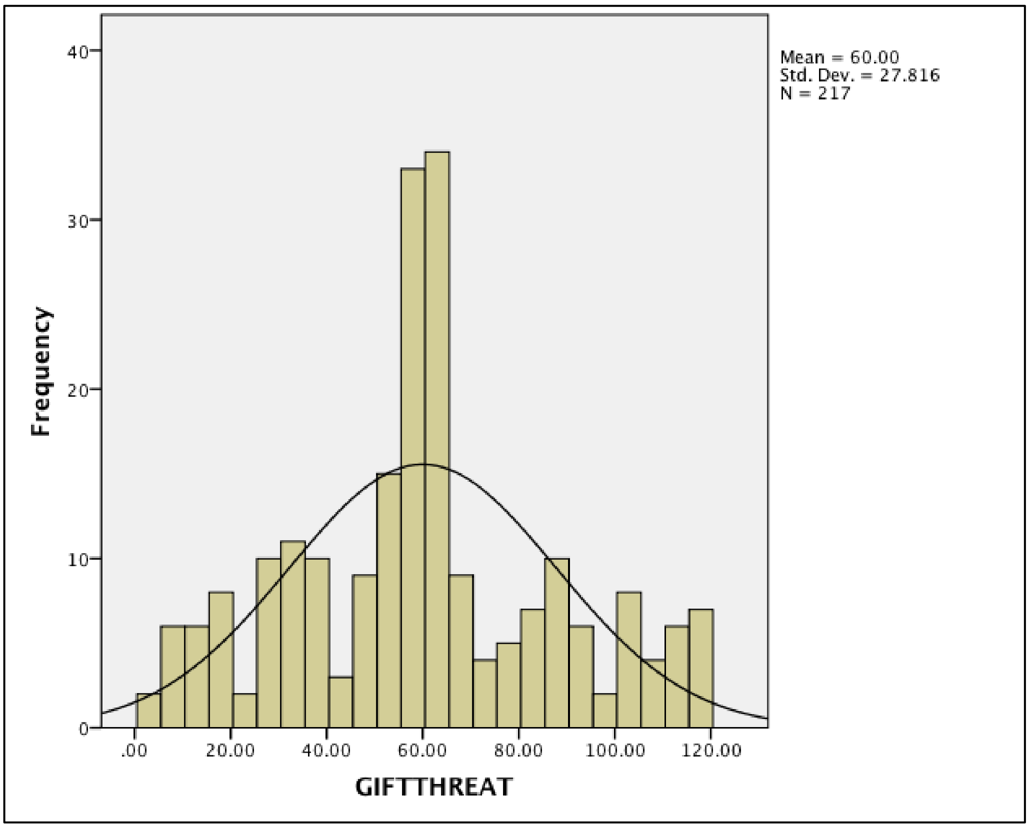


Figure 6.27: A histogram of the frequency of responses from the UK cohort to GiftThreat filtered by the breadth of fire experience

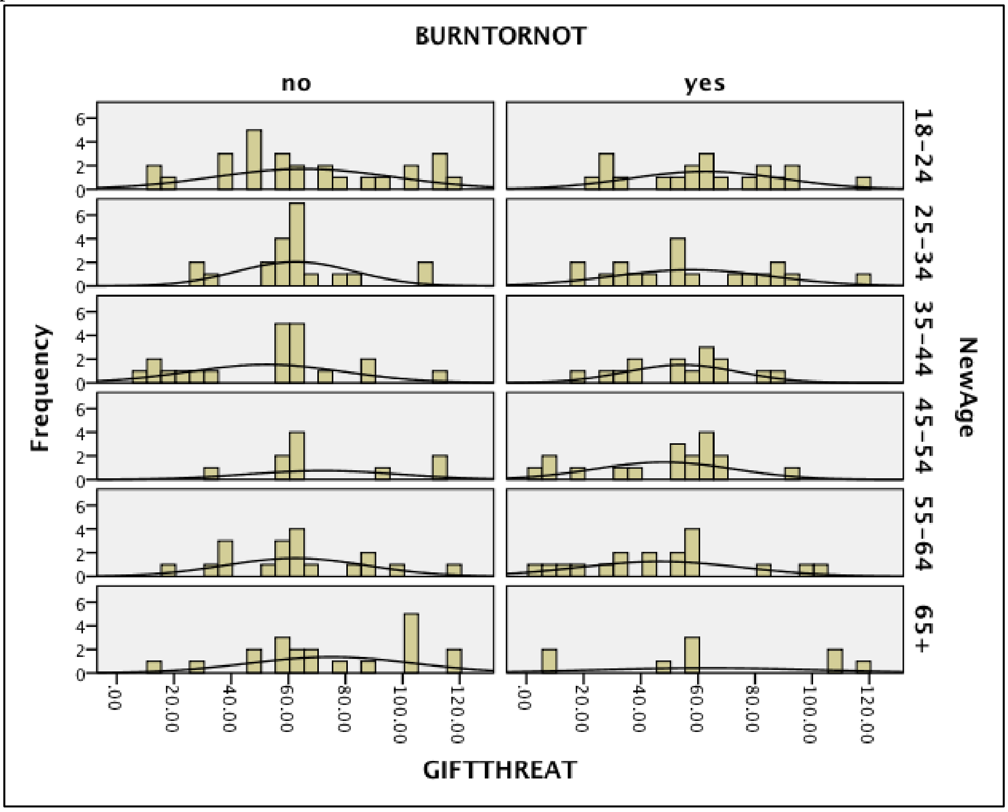
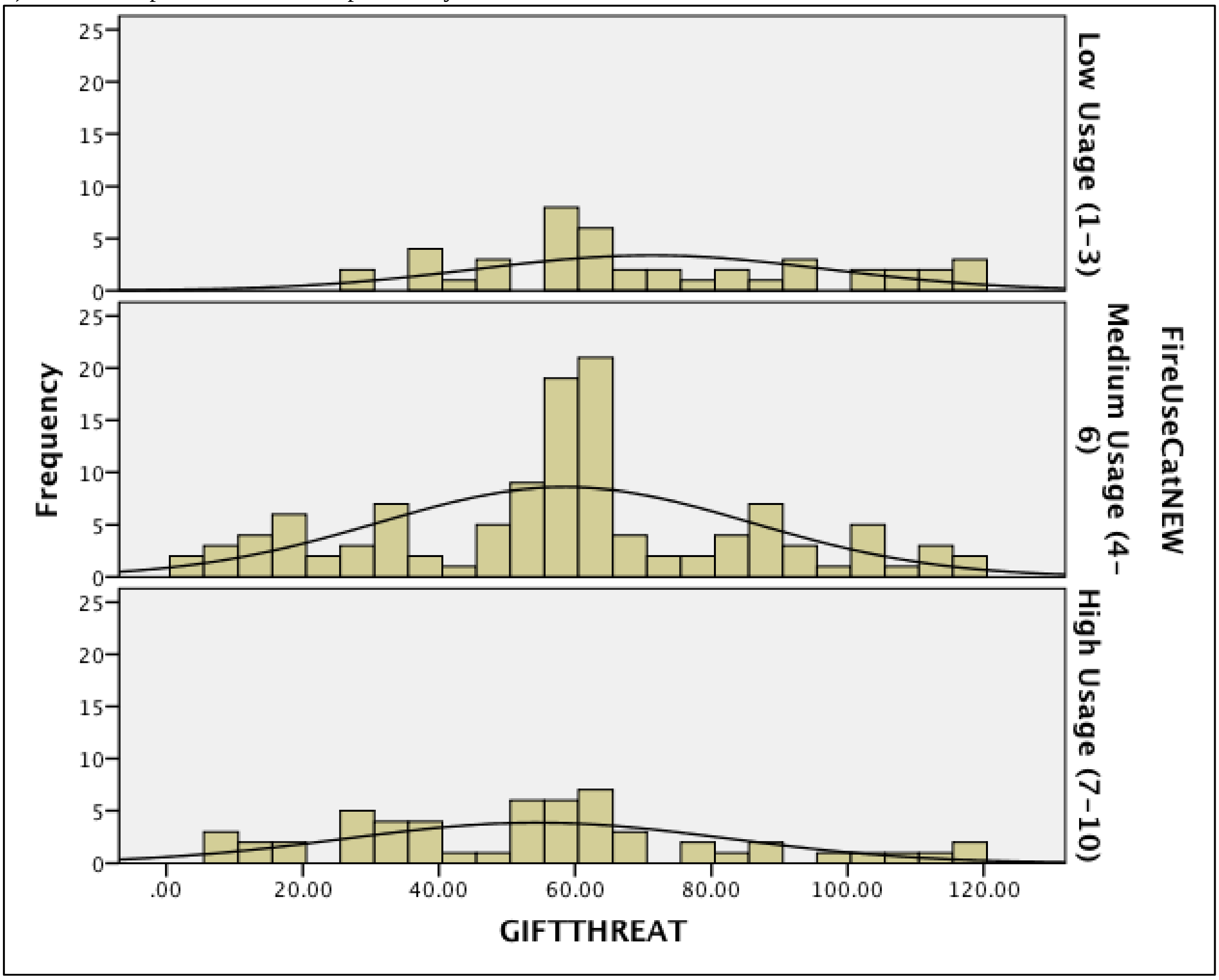


Figure 6.28: A histogram of the frequency of responses from the UK cohort to GiftThreat filtered by: i) age and, ii) whether respondents had been previously burnt or not



as a threat but these were heavily outnumbered by those who viewed fire as a gift, or had balanced views (Fig. 6.28). Respondents who had children viewed fire as more as a gift than a threat (Table 6.11). While this relationship was not statistically significant (p = 0.383) it is interesting to note as it may be the opposite of what would be expected of risk-averse parents.

	SEX	N	Mean Rank		
GiftThreat	MALE	95	104.13	Chi-Square	1.019
	FEMALE	122	112.80	df	1
	Total	217		Asymp. Sig.	0.313
	BURNTORNOT	N	Mean Rank		
GiftThreat	no	118	118.98	Chi-Square	6.537
	Yes	99	97.11	df	1
	Total	217		Asymp. Sig.	0.011
	PARENTHOOD	N	Mean Rank		
GiftThreat	NO	104	112.88	Chi-Square	0.761
	YES	113	105.43	df	1
	Total	217		Asymp. Sig.	0.383

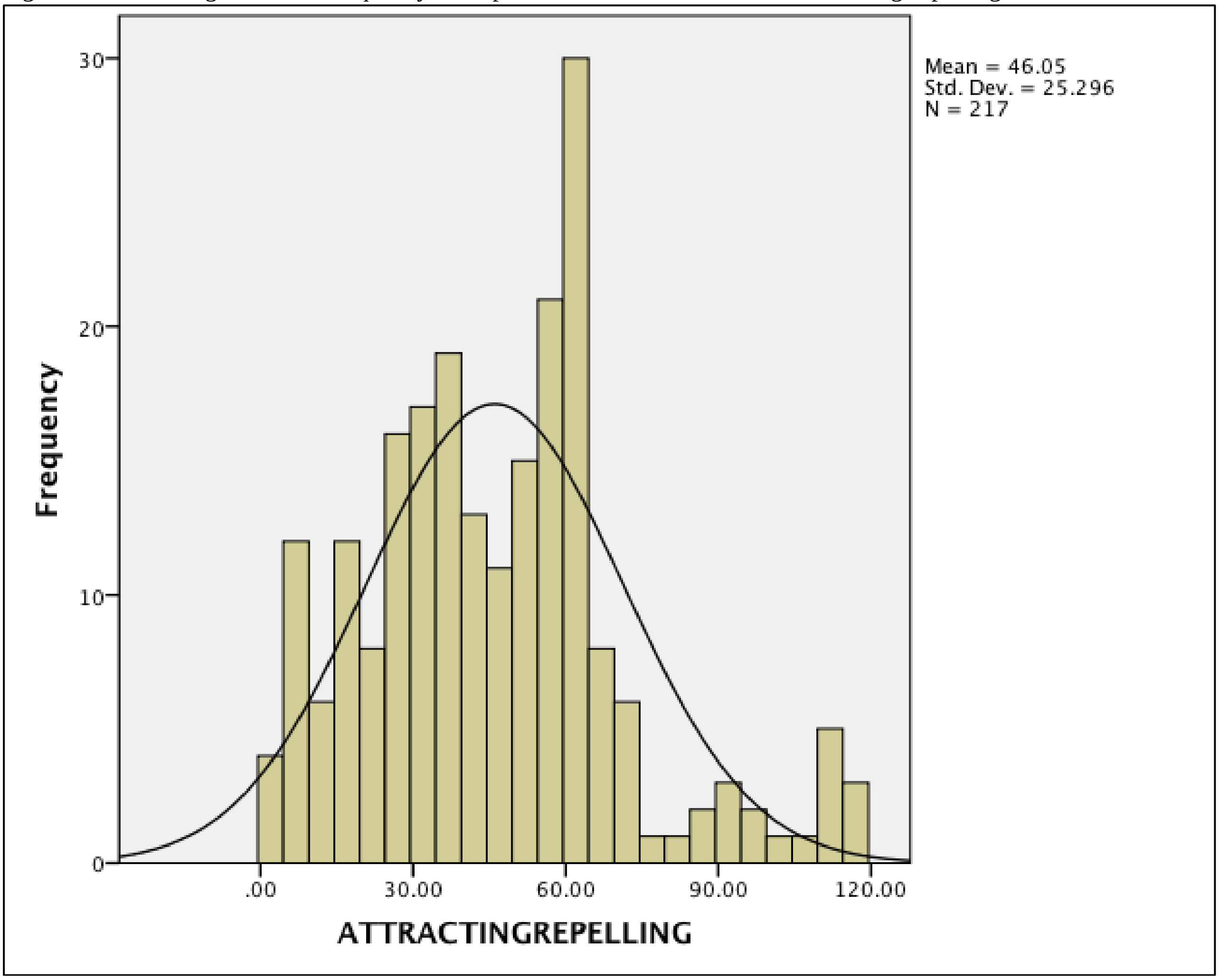
	NewAge	N	Mean Rank		
GiftThreat	18-24	47	116.45		
	25-34	40	109.38	Chi-Square	7.330
	35-44	36	96.65	df	5
	45-54	28	106.46	Asymp. Sig.	0.197
	55-64	37	95.77		
	65+	29	131.07		
	Total	217			
	Smokingstatus	N	Mean Rank		
GiftThreat	never smoked	117	106.74	Chi-Square	0.401
	ex-smoker	77	110.73	df	2
	current smoker	23	114.72	Asymp. Sig.	0.818
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
GiftThreat	RURAL	62	112.43	Chi-Square	0.259
	URBAN	155	107.63	df	1
	Total	217		Asymp. Sig.	0.611
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
GiftThreat	RURAL	60	110.61	Chi-Square	0.054
	URBAN	157	108.39	df	1
	Total	217		Asymp. Sig.	0.815
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
GiftThreat	RURAL	49	106.81	Chi-Square	0.077
	URBAN	168	109.64	df	1
	Total	217		Asymp. Sig.	0.781
	FireUseCatNEW	N	Mean Rank		
GiftThreat	Low Usage (1-3)	44	132.11	Chi-Square	8.401
	Medium Usage (4-6)	118	106.24	df	2
	High Usage (7-10)	55	96.43	Asymp. Sig.	0.015

Table 6.12: Kruskal-Wallis test data with GiftThreat as the test variable and a number of demographic grouping variables

AttractingRepelling

A strong psychological attraction to fire is clearly visible in the data collected from the UK cohort of this study (Fig 6.29) with participants responding that fire was much more attracting than repelling; although the largest concentration of data (the largest mode) along the spectrum was in the 55-65 range denoting those people who think that fire is both attracting and repelling in equal (or almost equal) measures (Fig. 6.29). The mean was 46.05 (St. Dev. 25.296) and the median was 46.0 with the majority of data clustering within the 0-50 range (those who view fire as very attractive or more attractive than repelling).

Figure 6.29: A histogram of the frequency of responses from the UK cohort to AttractingRepelling



Despite the uneven distribution observed in this dataset no statistically significant relationships were observable (Table 6.13); the closest variable to being significant was the breadth of fire-use experience which was significant at the 93% level but not the 95% (χ^2 = 5.474, p = 0.065).

	SEX	N	Mean Rank		
AttractingRepelling	MALE	95	106.31	Chi-Square	0.311
	FEMALE	122	111.10	df	1
	Total	217		Asymp. Sig.	0.577
	BURNTORNOT	N	Mean Rank		
AttractingRepelling	No	118	115.22	Chi-Square	2.540
	Yes	99	101.59	df	1
	Total	217		Asymp. Sig.	0.111
	PARENTHOOD	N	Mean Rank		
AttractingRepelling	NO	104	113.45	Chi-Square	1.002
	YES	113	104.91	df	1
	Total	217		Asymp. Sig.	0.317

	NewAge	N	Mean Rank		
AttractingRepelling	18-24	47	123.32		
	25-34	40	98.06	Chi-Square	8.854
	35-44	36	107.47	df	5
	45-54	28	103.46	Asymp. Sig.	0.115
	55-64	37	93.39		
	65+	29	128.03		
	Total	217			
	Smokingstatus	N	Mean Rank		
AttractingRepelling	never smoked	117	106.96	Chi-Square	0.396
	ex-smoker	77	110.16	df	2
	current smoker	23	115.50	Asymp. Sig.	0.820
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
AttractingRepelling	RURAL	62	114.54	Chi-Square	0.676
	URBAN	155	106.78	df	1
	Total	217		Asymp. Sig.	0.411
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
AttractingRepelling	RURAL	60	115.28	Chi-Square	0.829
	URBAN	157	106.60	df	1
	Total	217		Asymp. Sig.	0.363
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
AttractingRepelling	RURAL	49	108.01	Chi-Square	0.016
	URBAN	168	109.29	df	1
	Total	217		Asymp. Sig.	0.900
	FireUseCatNEW	N	Mean Rank		
AttractingRepelling	Low Usage (1-3)	44	127.18	Chi-Square	5.474
	Medium Usage (4-6)	118	107.37	df	2
	High Usage (7-10)	55	97.95	Asymp. Sig.	0.065

Table 6.13: Kruskal-Wallis test data with AttractingRepelling as the test variable and a number of grouping variables

CleansingDestructive

Results from the UK cohort show that it is the destructive rather than the cleansing nature of fire that dominates the UK mind-set; the mean is 78.184 (St. Dev. 24.240) and the median is 80.0. A large mode exists in the 55-65 range (those who have balanced views between fire's cleansing and destructive properties), with other small modes outside the predicted normal distribution of data visible in the 85-95 and the 110-120 ranges (Fig. 6.30). No significant relationships were found between CleansingDestructive and the grouping variables tested for (Table. 6.14). While females in the UK cohort found fire to be more destructive than males (Fig. 6.31), this was not significant as demonstrated by similarities between distributions.

Figure 6.30: A histogram of the frequency of responses from the UK cohort to CleansingDestructive

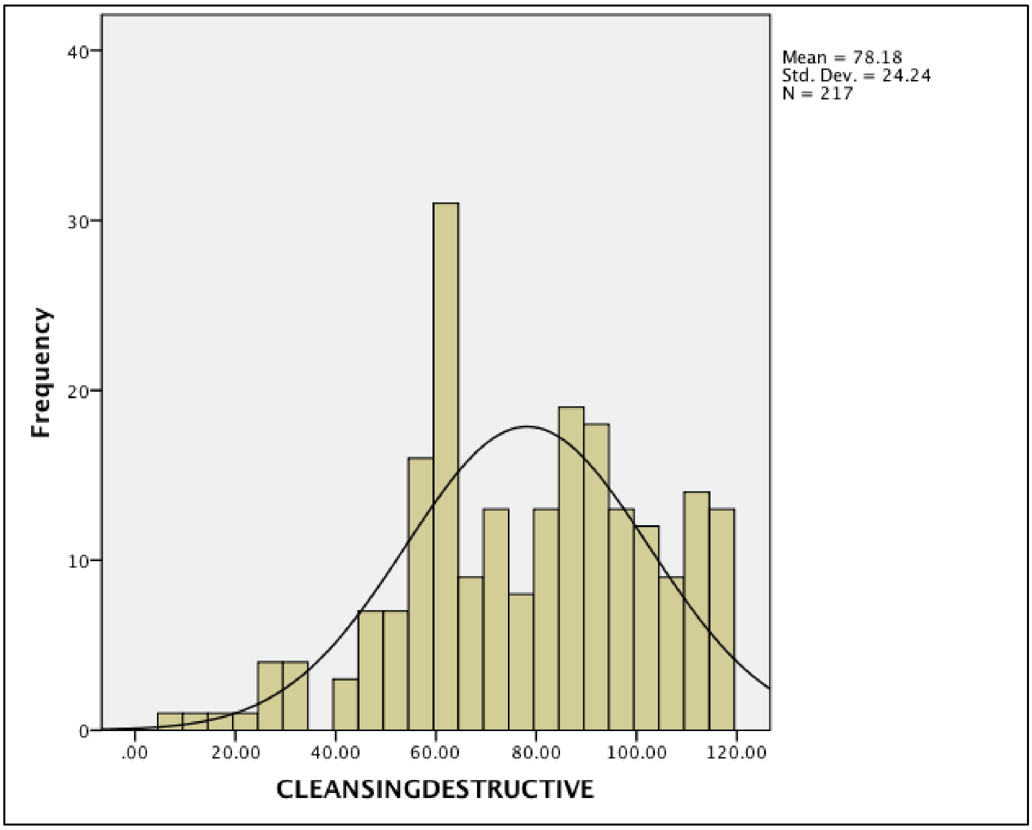
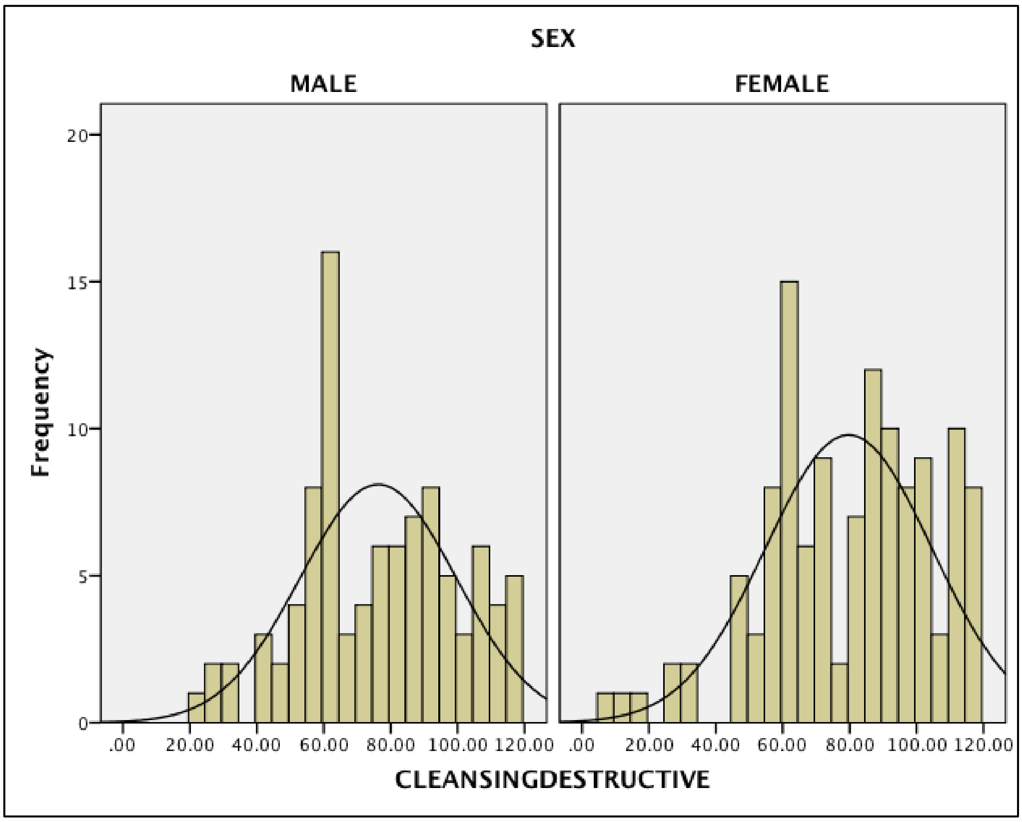


Figure 6.31: A histogram of the frequency of responses from the UK cohort to CleansingDestructive filtered by sex



	SEX	N	Mean Rank		
CleansingDestructive	MALE	95	102.83	Chi-Square	1.632
	FEMALE	122	113.80	df	1
	Total	217		Asymp. Sig.	0.201
	BURNTORNOT	N	Mean Rank		
CleansingDestructive	no	118	114.39	Chi-Square	1.904
	yes	99	102.58	df	1
	Total	217		Asymp. Sig.	0.168
	PARENTHOOD	N	Mean Rank		
CleansingDestructive	NO	104	108.09	Chi-Square	0.42
	YES	113	109.84	df	1
	Total	217		Asymp. Sig.	0.838
	NewAge	N	Mean Rank		
CleansingDestructive	18-24	47	107.21		
	25-34	40	92.06	Chi-Square	6.551
	35-44	36	103.86	df	5
	45-54	28	110.27	Asymp. Sig.	0.256
	55-64	37	120.09		
	65+	29	126.26		
	Total	217			
	Smokingstatus	N	Mean Rank		
CleansingDestructive	never smoked	117	108.45	Chi-Square	0.653
	ex-smoker	77	106.91	df	2
	current smoker	23	118.78	Asymp. Sig.	0.721
	Total	217			
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
CleansingDestructive	RURAL	62	106.47	Chi-Square	0.141
	URBAN	155	110.01	df	1
	Total	217		Asymp. Sig.	0.707
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
CleansingDestructive	RURAL	60	106.09	Chi-Square	0.178
	URBAN	157	110.11	df	1
	Total	217		Asymp. Sig.	0.673
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
CleansingDestructive	RURAL	49	108.57	Chi-Square	0.003
	URBAN	168	109.13	df	1
	Total	217		Asymp. Sig.	0.957
	FireUseCatNEW	N	Mean Rank		
CleansingDestructive	Low Usage (1-3)	44	117.76	Chi-Square	2.075
	Medium Usage (4-6)	118	110.03	df	2
	High Usage (7-10)	55	99.78	Asymp. Sig.	0.354

Table 6.14: Kruskal-Wallis test data with ComfortingStressful as the test variable and a number of demographic grouping variables

UK cohort summary

None of the datasets generated by the UK cohort was normally distributed. Twenty-one statistically significant relationships were identified overall between the eleven word-pairs and the demographic variables. ProtectiveRisky (rev) and ExcitingDangerous were found to have the most number of statistically significant relationships computed from the nine grouping variables tested for with four each (Table. 6.15); SocialViolent (rev) had three statistically significant relationships. Three word-pairings (WarmingBurning [rev], AttractingRepelling and CleansingDestructive) had zero statistically significant relationships.

Of the nine grouping variables tested for, the 'breadth of fire-use experience' was found to be significant on the most number of word –pair variables (7/11); sex, whether people had been previously burnt or not and age all being observed to be significant 3/11 times. Four variables (smoking status, under 10 living environment, adolescent living environment and current living environment) were calculated as having no statistically significant relationships within data collected from the UK cohort (Table 6.15). Overall the fact that twenty-one statistically significant relationships were identified provides excellent material with which to compare and contrast data collected from the UK cohort with those from the Batwa and NBA cohorts.

Variable	Number of statistically significant relationships									
	Sex	Burnt Or Not	Parenthood	New Age	Smoking Status	Under 10 living Environment	Adolescent living Environment	Current Living Environment	Fire-use Experience	TOTAL
PROTECTIVERISKY(rev)	Y	Y	N	Y	N	N	N	N	Y	4
EXCITINGDANGEROUS	N	Y	Y	Y	N	N	N	N	Y	4
WARMINGBURNING(rev)	N	N	N	N	N	N	N	N	N	0
SOCIALVIOLENT(rev)	Y	N	N	Y	N	N	N	N	Y	3
SAFESCARY	N	Y	Y	Y	N	N	N	N	N	3
USEFULHAZARDOUS(rev)	Y	N	N	N	N	N	N	N	Y	2
COMFORTINGSTRESSFUL	N	N	N	N	N	N	N	N	Y	1
FRIENDLYFEARSOME	Y	N	N	N	N	N	N	N	Y	2
GIFTTHREAT	N	Y	N	N	N	N	N	N	Y	2
ATTRACTINGREPELLING	N	N	N	N	N	N	N	N	N	0
CLEANSINGDESTRUCTIVE	N	N	N	N	N	N	N	N	N	0
TOTAL	4	4	2	4	0	0	0	0	7	21

Table 6.15: A summary of the number of statistically significant relationships obtained by Kruskal-Wallis testing data collected from the UK cohort (95% confidence level)

C2 – The Batwa Cohort

Frequencies

Category	Variable	Batwa
	N	225
		%
Sex	Male	34.7
	Female	65.3
Parenthood	No children	18.7
	Children under age 18	72.0
	Adult children	9.3
New Age	18-24	33.3
	25-34	29.8
	35-44	16.9
	45-54	10.2
	55-64	6.2
	65+	3.6
Smoking status	Never smoked	24.4
	Ex-smoker	29.3
	Current smoker	46.2
Burnt or not	No	20.4
	Yes	79.6
How badly burnt	Numbers burnt **(not %)**	N = 179
This data only looks at those who answered that they had been burnt	Slightly	52.5
	Moderately	25.1
	Severely	22.4
Fire-uses individual (% yes)	Keeping insects away	96.9
	Cooking food	100
	Keeping warm	100
	Lighting	100
	Signalling	96.4
	Cleaning and cleansing	96.4
	Boiling water	100
	Killing plants	55.6
	Burning rubbish	96.0
	Making things	77.3
Fire usage combined	Low Usage (1-3)	0
	Medium Usage (4-6)	0.9
	High Usage (7-10)	99.1
Under 10 living environment (predominant)	Rural	96.0
	Urban	4.0
Age 10 to 18 living environment (predominant)	Rural	95.1
	Urban	4.9
Current living environment	Rural	95.6
	Urban	4.4

Table 6:16: Frequencies of certain demographic descriptors from the Batwa sample (N=225)

To collect the data from the Batwa 17 different Batwa settlements were visited, two of which were visited twice (Mushanje and Rwamahano) making a total of 19 separate visits. These visits were done over a total of 10 days (see table 6.17) resulting in 226 completed interviews. However during one of the interviews with a very old lady from Ruceeri (24/11/2015) it was clear that she did not understand the methodology and how to use the data collection tools; therefore her responses were declared invalid and discarded (although the interview was completed in full so no stigma or embarrassment would be experienced by the respondent).

Batwa Data Collection			
Date	Location	Completed interviews	Total
14/11/2015	Kashasha	16	16
15/11/2015	Mushanje 1	25	41
22/11/2015	Rwamahano 1	12	53
23/11/2015	Gateera	23	76
24/11/2015	Ruceeri	25	101
24/11/2015	Bigina	5	106
25/11/2015	Mikingo	2	108
25/11/2015	Gahinga	13	121
25/11/2015	Kanyabukungu	4	125
25/11/2015	Mutanda ECC	3	128
26/11/2015	Rwamahano 2	11	139
26/11/2015	Kagano	7	146
26/11/2015	Kamagoye	10	156
27/11/2015	Musasa	19	175
27/11/2015	Kubule	2	177
08/12/2015	Kyevu	4	181
08/12/2015	Murambo	15	196
09/12/2015	Murubindi	28	224
09/12/2015	Mushanje 2	2	226

Table 6.17: The location name, date and number of interviews performed at each location collecting the data for the Batwa cohort (N=225)

Table 6.16 shows the demographic frequencies and responses to some key variables from the Batwa cohort. Of the 225 people recruited to make up the Batwa cohort 78 (34.7%) were male and 147 (65.3%) were female. This imbalance may be an artefact of the twin facts that females were possibly happier to wait patiently to answer (although nearly all Batwa that we encountered were very happy and enthusiastic to participate), with waiting times often exceeding two hours due to the nature of the individual interview methodology; men were more likely to be out working while females were in the settlements cooking and looking after children. 42 people had no children (18.7%), 162 respondents said their youngest child was under the age of 18 (72.0%) and 21 people responded that their youngest child was 18+ (9.3%). 55 people stated that they had never smoked (24.4%), 104 were current smokers (46.2%) and 66 people classified themselves as ex-smokers (29.3%). 46 people stated that they had never been burnt (20.4%) while 179 stated that they had (79.6%); of those who said they had been burnt 94 (52.5%) classified their most serious burn as 'slight' (1-40), 45 (25.1%) as 'moderately serious' (41-80) and 40 people (22.4%) as 'severe' (81-120).

Of the ten different fire-uses that we specifically asked respondents if they had personal experience of, the most frequent were 'cooking food', 'keeping warm', lighting and boiling water; all of which gained 100% positive responses. Killing plants (55.6%) and making things (77.3%) were the only fire-uses that less than ninety-five percent of Batwa respondents admitted to having experience of. When we asked the 'making things' question, the specific wording used was: "Have you ever made anything with fire that was not food?" thus differentiating this from cooking or other kinds of fire-based food preparation. As some respondents appeared to struggle with this question, if a positive response was provided respondents were then asked to provide examples (e.g. making jewellery or fixing rubber boots – both common responses) thus corroborating the results. When the total number of different fire-uses were collated and placed into three categories (Low [1-3], Medium [4-7] and High [8-10]) 0 respondents were classified as 'Low' (0%), 2 as 'Medium' (0.9%) and 223 as 'High' (99.1%); please note that the frequency of experience was not requested or collected – only whether each respondent had personal experience of that particular fire-use. The Batwa population had such a high frequency of 'High' fire-users that later on in the analysis it was not possible to test for statistical significance with this variable as insufficient statistical power was generated; therefore analysis of this variable is not presented.

Data analysis shows that of the Batwa cohort 216 (96.0%) classified their 'under 10 living environment as predominantly 'rural', while 9 (4.0%) classified as predominantly 'urban'. This altered to 214 rural (95.1%) and 11 urban (4.9%) from 'age 10 to age 18 living environment'. When questioned about their 'current living environment' 215 people classified as rural (95.6%) and 10 as urban (4.4%). This highlights the static status of Batwa communities with very little population movement and migration. These statistics are exacerbated by the fact that of the three urban Batwa communities the research team visited, one community (but the largest in terms of community members) was not happy with our refusal to pay respondents in cash and/or alcohol. At that community only two consenting adults were interviewed, all other adults refused. This was the only community that we had this problem with during the entire period of fieldwork with the Batwa. Due to the significant imbalance between the number of urban and rural respondents significance could not be determined within the data and therefore analysis is not presented. The Batwa sample within this study was placed into six different age groups (see table 6.16). The largest group was 18-24 (33.3%), with the smallest group being the 65+ (3.6). The distribution resembles a population pyramid from a developing country (Korenjak-Černe et al. 2014), and is similar to what would be expected of a random cross-section of an African population.

Means

An analysis of the eleven word-pairings from section one of the questionnaire identified that the responses within the population were diverse with the range of answers exceeding 110 (out of a possible 120) for every word-pairing. All of the standard deviations fell within the range of 28-36. It is reiterated that these word-pairings were specifically chosen as NOT to be exact opposites of each other; while not being direct opposites they can be viewed as opposite ends of a spectrum. Respondents could choose between either a positive or negative emotion/connotation. While not being exact opposites word-pairs did contrast providing very different concepts for respondents to find their own personal balance between.

For any word-pairing a mean of > 60 denotes that on average Batwa respondents' associated negative rather than positive emotions or attitudes towards fire within that word-pairing. While a mean of < 60 denotes that on average Batwa respondents' associated positive rather than negative emotions or attitudes towards fire within that word-pairing. The more distant the mean average is from 60 denotes the greater preference the population has for one word over the other. Observation of the data shows that the most 'positive' feeling about fire was 'useful' (from the 'usefulhazardous' word-pair) with a mean of 38.431 and a median of 33.0, while the most 'negative' was 'repelling' with a mean of 61.920 and a median of 58.0 (from the word-pair 'attractingrepelling'). The word-pairs that elicited on average the most balanced responses were 'comfortingstressful' with a mean of 60.124 (median = 50.0 – [which highlights the fact that a substantial minority of the Batwa must have classified fire as 'highly stressful]) and 'cleansingdestructive' with a mean of 60.747 (median = 60.0).

Analysis of the Batwa data shows that of the eleven word-pairings seven had mean averages that can be classed as showing that the Batwa responded 'positively' (mean was <55), while nine had median averages <55 (Table 6.18). This suggests that within the Batwa mind-set fire is viewed positively. The three word-pairings that had a mean greater than 60 (comforting-stressful, attractingrepelling and cleansingdestructive) were all only slightly negative (range 60-62 – none of which had a median >60) suggesting that across the population surveyed an awareness exists of the dangers and risks of fire but within the mind-set of respondents these do not outweigh the benefits. Very significantly, of the eleven word-pairings none of the medians was greater than 60 (ten were less than 60 [range 33-58] and one was exactly 60 [cleansingdestructive]; this neatly highlights the positive way that fire is perceived and thought of within the Batwa cohort.

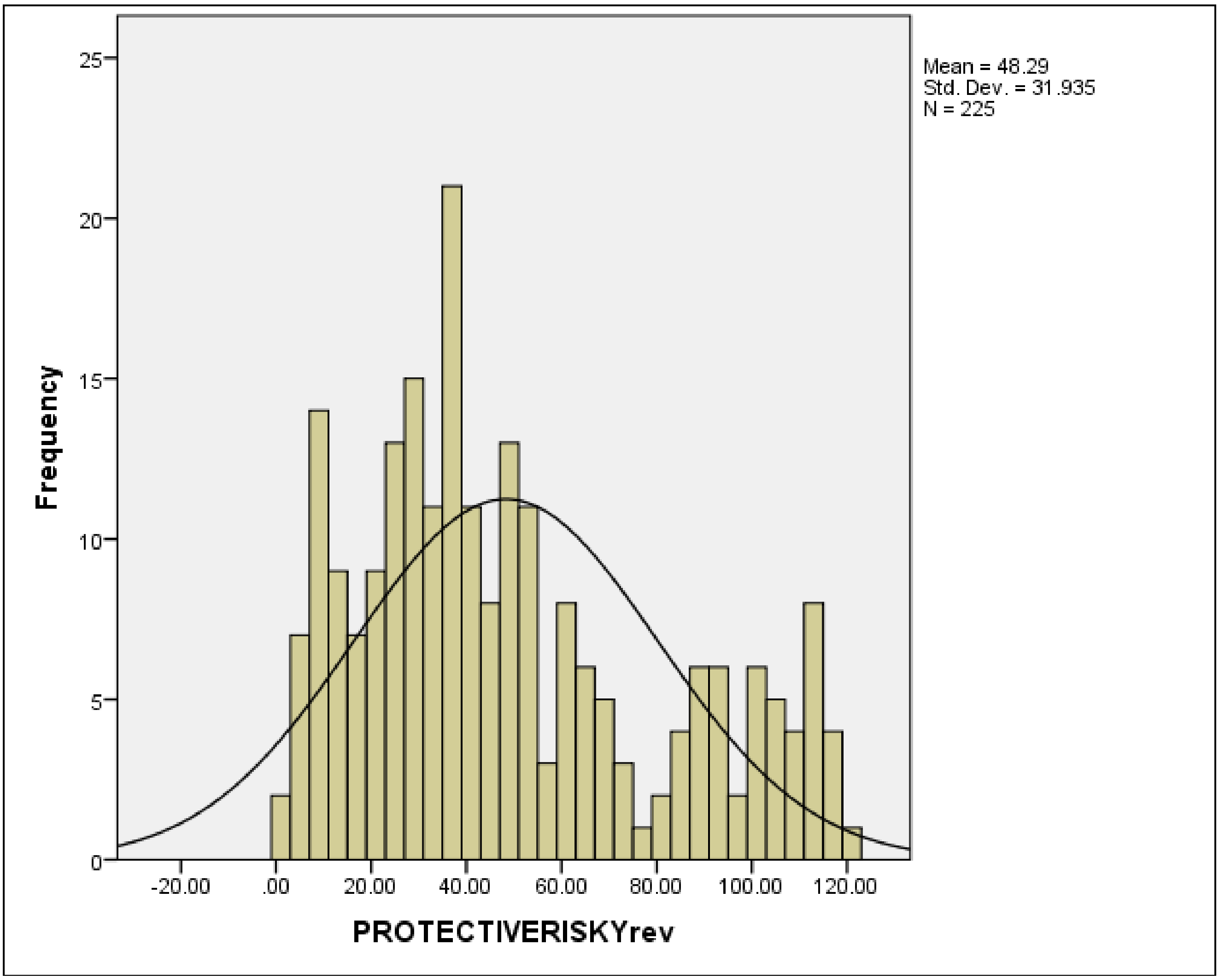
All of the results from the Batwa cohort word-pairings were not normally distributed and therefore statistical analysis specific to non-normally distributed data was applied. Most data distributions could be described as multi-modal but on occasions bi-modal and tri-modal distributions were observed.

	Range	Minimum	Maximum	Mean	Std. Error of Mean	Std. Dev.	Coefficient of Variance	Median
PROTECTIVERISKYrev	118.00	1.00	119.00	48.289	2.129	31.935	0.661	41.0
EXCITINGDANGEROUS	112.00	6.00	118.00	53.369	1.942	29.128	0.546	44.0
WARMINGBURNINGrev	112.00	3.00	115.00	53.409	2.185	32.771	0.614	45.0
SOCIALVIOLENTrev	112.00	3.00	115.00	44.084	1.916	28.738	0.652	37.0
SAFESCARY	118.00	2.00	120.00	58.036	2.256	33.833	0.583	48.0
USEFULHAZARDOUSrev	112.00	3.00	115.00	38.431	1.887	28.306	0.737	33.0
COMFORTINGSTRESSFUL	116.00	4.00	120.00	60.124	2.159	32.392	0.539	50.0
FRIENDLYFEARSOME	118.00	2.00	120.00	55.124	2.334	35.016	0.635	46.0
GIFTTHREAT	116.00	2.00	118.00	55.440	2.291	34.366	0.620	48.0
ATTRACTINGREPELLING	114.00	6.00	120.00	61.920	2.334	35.012	0.565	58.0
CLEANSINGDESTRUCTIVE	118.00	2.00	120.00	60.747	2.276	34.144	0.562	60.0

Table 6.18: Mean averages and related statistics for the Batwa sample (N=225)

ProtectiveRiskyrev

Figure 6.32: A histogram of the frequency of responses from the Batwa cohort to ProtectiveRisky(rev)



Data is ‘bi-modal’ (Fig.6.32) with a mean response of 48.29 (Std.dev = 31.935) and a median of 41.0. Low results are demonstrated in Fig. 6.32 by a large mode of data (20-55 range) correlating to respondents stating they perceive fire as being more protective than risky. A second smaller mode can be observed clustering around the 80-120 range representing those respondents who perceived fire as being more risky than protective. Data shows that the Batwa cohort perceives that fire is significantly more protective than risky; a pattern contrary to responses from the UK cohort.

Figure 6.33: A histogram of the frequency of responses from the Batwa cohort to ProtectiveRisky(rev) filtered for age of the respondent

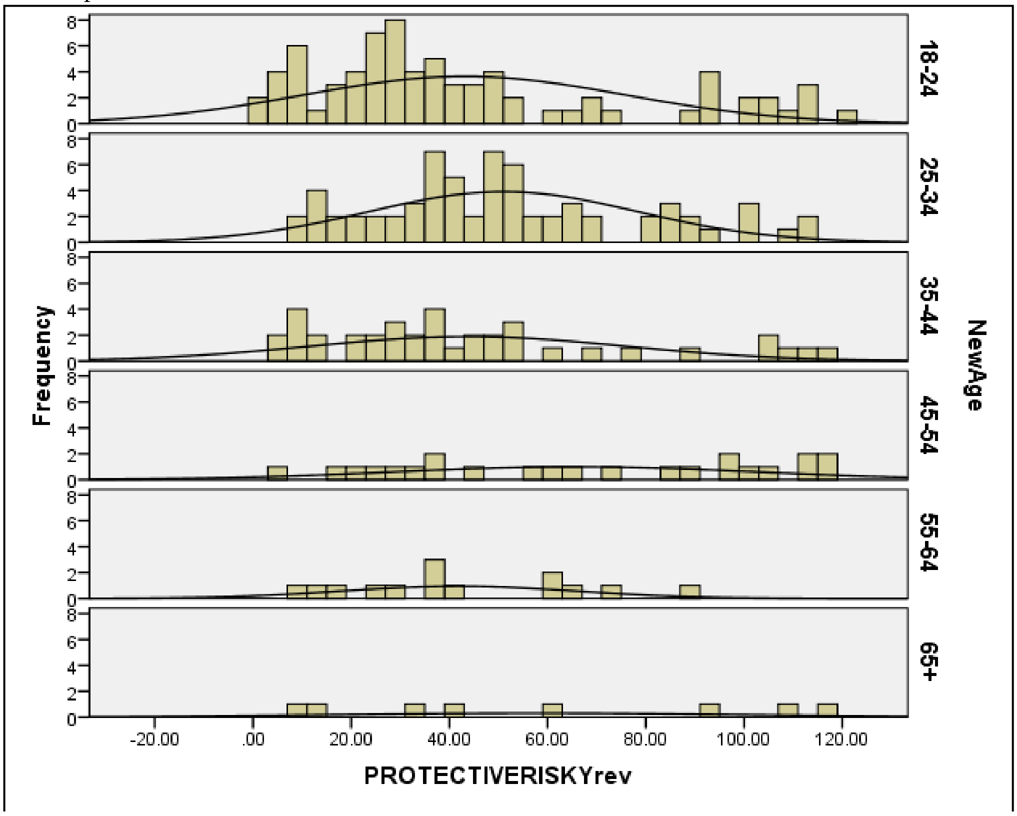
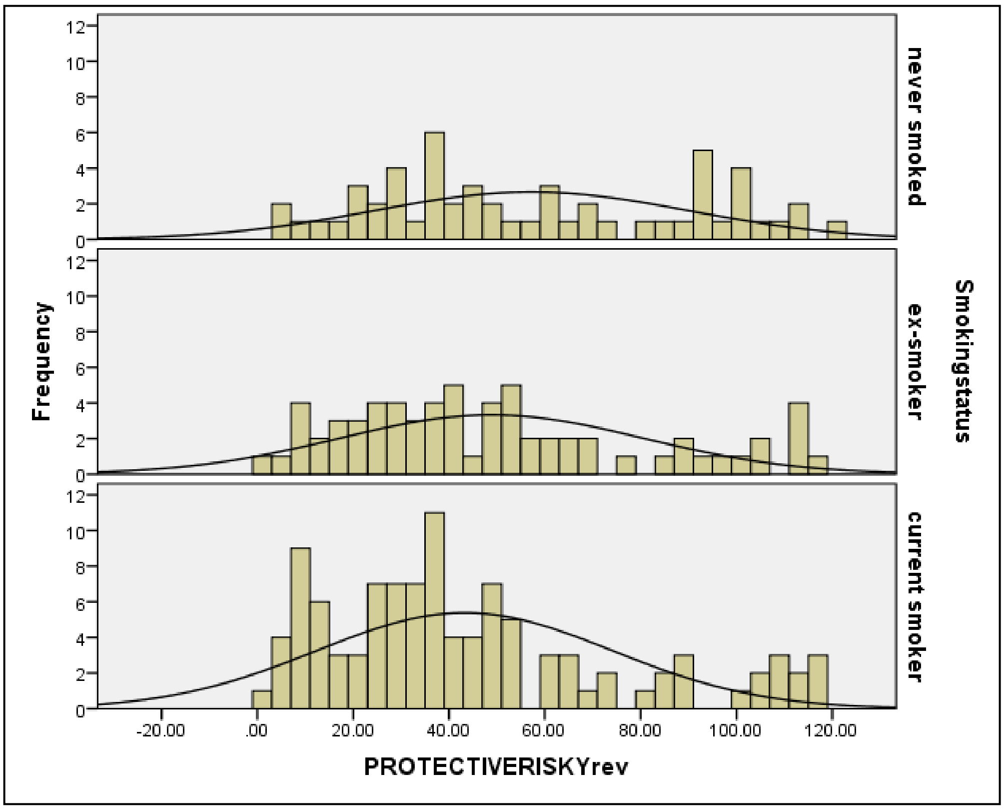


Figure 6.34: A histogram of the frequency of responses from the Batwa cohort to ProtectiveRisky(rev) filtered for smoking status



Kruskal-Wallis testing found two statistically significant variables that impact on this word-pairing; age (χ^2 = 11.515, p = 0.042) and smoking status (χ^2 = 6.901, p = 0.032) (Table 6.19). The youngest age group (18-24) thought that fire was more protective than all the other age groups, with the 35-44 and 55-64 age groups responding that fire was more protective than the 25-34, 45-54 and 65+ age groups (Fig. 6.33); the 45-54 group perceive fire to be most risky. Current smokers were more likely to think of fire as protective with 'never-smokers' answering that they found fire to be more risky than the other groups (Fig. 6.34).

	SEX	N	Mean Rank		
ProtectiveRiskyrev	MALE	78	113.43	Chi-Square	0.005
	FEMALE	147	112.77	df	1
	Total	225		Asymp. Sig.	0.943
	BURNTORNOT	N	Mean Rank		
ProtectiveRiskyrev	no	46	121.47	Chi-Square	0.979
	yes	179	110.82	df	1
	Total	225		Asymp. Sig.	0.322
	PARENTHOOD	N	Mean Rank		
ProtectiveRiskyrev	NO	41	101.35	Chi-Square	1.606
	YES	184	115.60	df	1
	Total			Asymp. Sig.	0.205
	NewAge	N	Mean Rank		
ProtectiveRiskyrev	18-24	75	99.31		
	25-34	67	123.84	Chi-Square	11.515
	35-44	38	102.8	df	5
	45-54	23	142.76	Asymp. Sig.	0.042
	55-64	14	105.07		
	65+	8	127.31		
	Total	225			
	Smokingstatus	N	Mean Rank		
ProtectiveRiskyrev	never smoked	55	130.57	Chi-Square	6.901
	ex-smoker	66	115.22	df	2
	current smoker	104	102.30	Asymp. Sig.	0.032
	Total	225			

Table 6.19: Kruskal-Wallis test data with ProtectiveRisky (rev) as the test variable and a number of grouping variables

ExcitingDangerous

The mean was 53.37 (Std. Dev. = 29.128) and the median was 44.0, showing that the Batwa cohort perceived fire as being more exciting than dangerous (Fig. 6.35). A multi-modal distribution is visible (Fig. 6.35) with the largest and most easily identifiable mode in the 25-50 range representing people who think fire is very exciting but also a little dangerous (the median falls within this range). A small but significant portion of the Batwa population did however think that fire was very dangerous and not very exciting at all (100-120 range) which makes up the second, much smaller, mode. This second mode appears to be responsible for the large difference between the mean and median values as this strong strength of feeling heavily impacts the mean.

Age was observed to be significant in determining how participants responded ($\chi^2 = 15.492$, $p = 0.008$ [Table 6.20 / Fig. 6.36]). Younger age groups found fire to be more exciting than older age groups. The exception to this was the 55-64 age group (N = 14) who responded that, on average, they found fire to be more exciting than all of the other age groups. Not a single respondent from the 65+ age group responded that fire was more exciting than dangerous (range 1-59) with all responses being > 60.

Figure 6.35: A histogram of the frequency of responses from the Batwa cohort to excitingdangerous

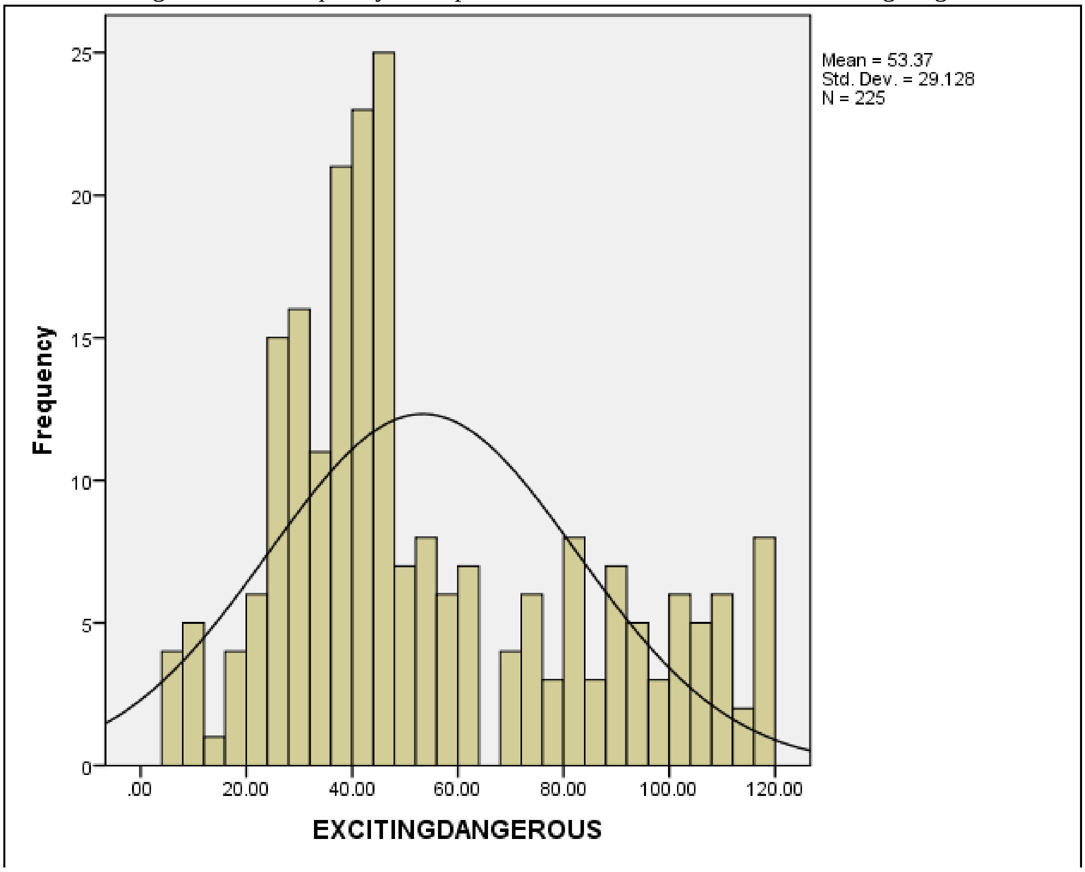
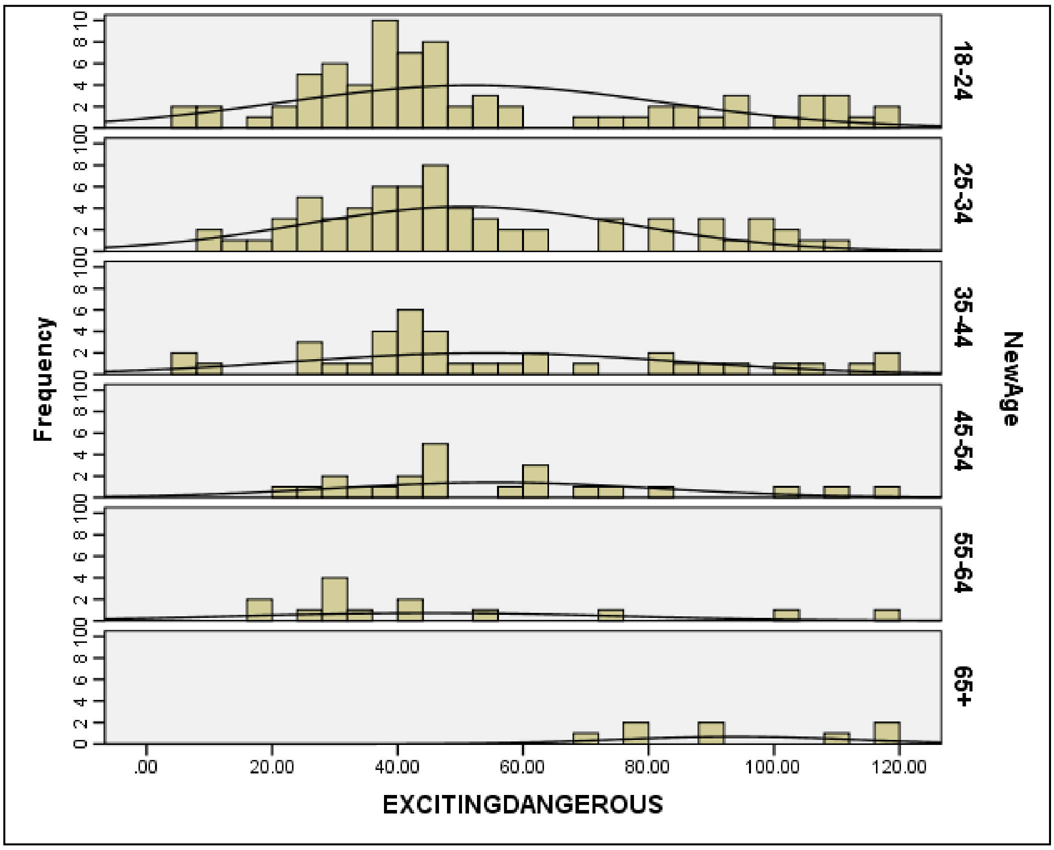


Figure 6.36: A histogram of the frequency of responses from the Batwa cohort to excitingdangerous filtered by age



	SEX	N	Mean Rank		
ExcitingDangerous	MALE	78	102.48	Chi-Square	3.121
	FEMALE	147	118.58	df	1
	Total	225		Asymp. Sig.	0.077
	BURNTORNOT	N	Mean Rank		
ExcitingDangerous	no	46	119.71	Chi-Square	0.614
	yes	179	111.28	df	1
	Total	225		Asymp. Sig.	0.433
	PARENTHOOD	N	Mean Rank		
ExcitingDangerous	NO	41	99.56	Chi-Square	2.139
	YES	184	115.99	df	1
	Total			Asymp. Sig.	0.144
	NewAge	N	Mean Rank		
ExcitingDangerous	18-24	75	107.65		
	25-34	67	109.64	Chi-Square	15.492
	35-44	38	116.67	df	5
	45-54	23	122.67	Asymp. Sig.	0.008
	55-64	14	86.61		
	65+	8	192.25		
	Total	225			
	Smokingstatus	N	Mean Rank		
ExcitingDangerous	never smoked	55	111.77	Chi-Square	0.119
	ex-smoker	66	115.30	df	2
	current smoker	104	112.19	Asymp. Sig.	0.942
	Total	225			

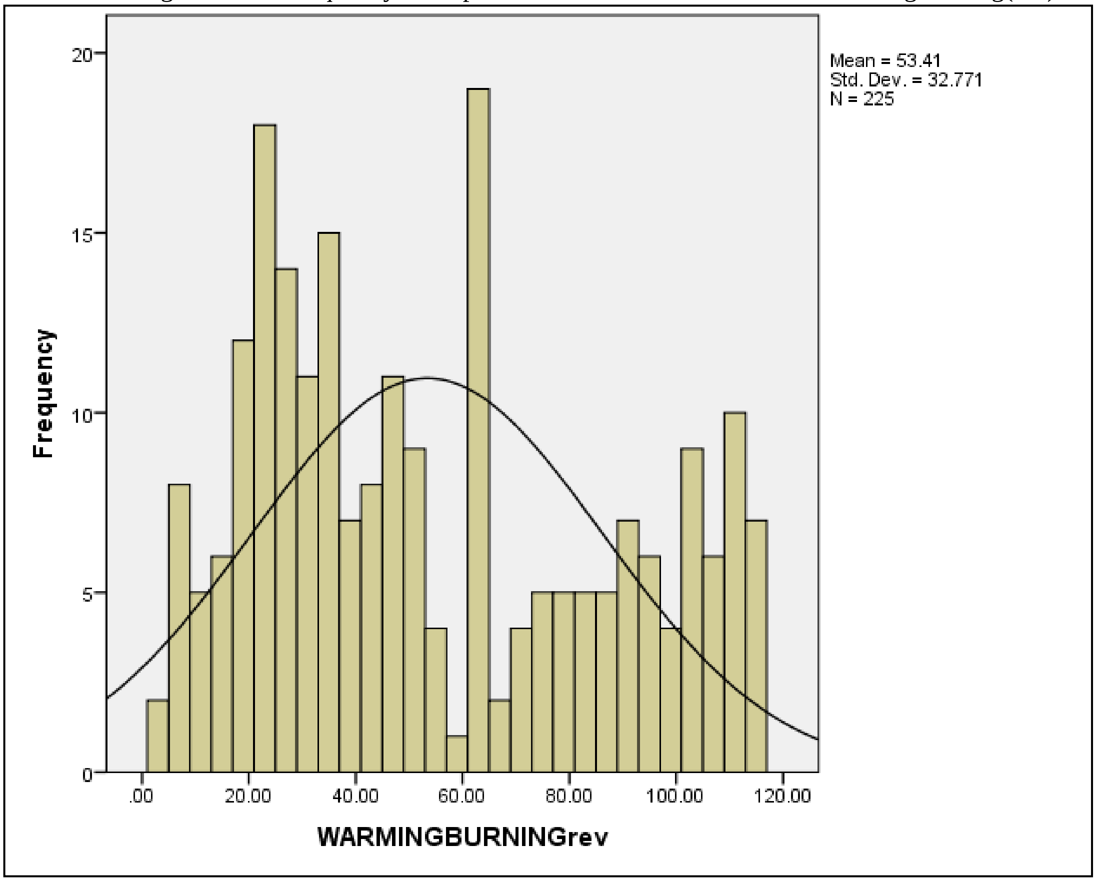
Table 6.20: Kruskal-Wallis test data with ExcitingDangerous as the test variable and a number of grouping variables

WarmingBurning (rev)

A mean of 53.41 (St. Dev. 32.771) and a median of 45.0 shows that fire is seen as more warming than burning by the Batwa. Data distributions are multi-modal (Fig. 6.37). The 5-35 range mode depicts those respondents who think fire is very warming and don't really think of fire as burning. A second prominent mode is a very narrow mode (range 60-65) of 18 people who think fire is both burning and warming, but if they had to choose would just about err on the side of burning (Fig. 6.37). A third easily identifiable mode in the 90-120 range denotes those people who think of fire very strongly as burning and not warming.

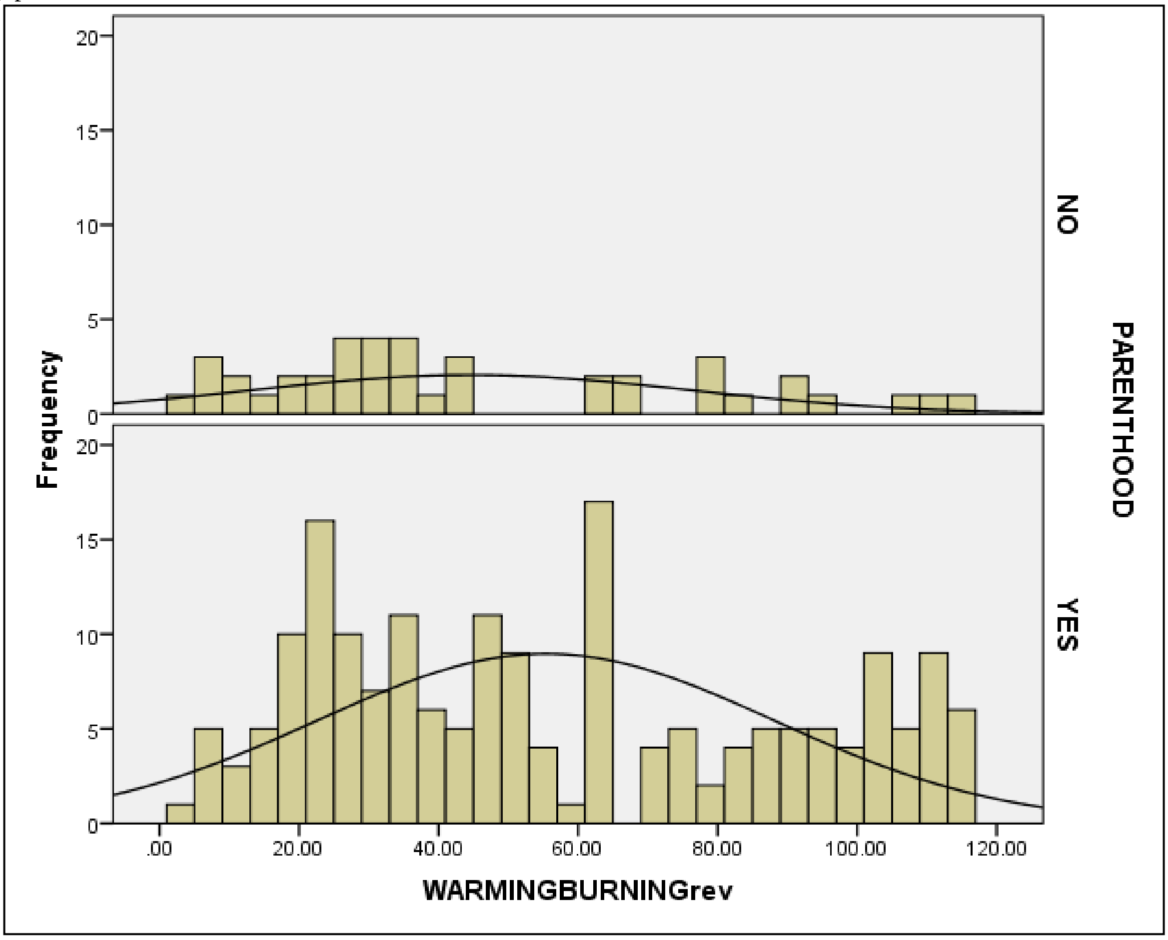
While Kruskal-Wallis testing did not identify any statistically significant relationships (Table. 6.21) 'Parenthood' was almost significant at the 95% confidence level (χ^2 = 3.750, p = 0.053); perhaps it would have been significant if more than 18.7% of Batwa participants had

Figure 6.37: A histogram of the frequency of responses from the Batwa cohort to WarmingBurning(rev)



been childless. Those from the Batwa cohort who are already parents can be seen to be mostly responsible for the nature of all three modes identified in Fig 6.37 showing the large impact made on responses to this word-pairing by being a parent (Fig.6.38), even if this relationship cannot be classified as statistically significant at the 95% confidence level.

Figure 6.38: A histogram of the frequency of responses from the Batwa cohort to WarmingBurning(rev) filtered by parenthood



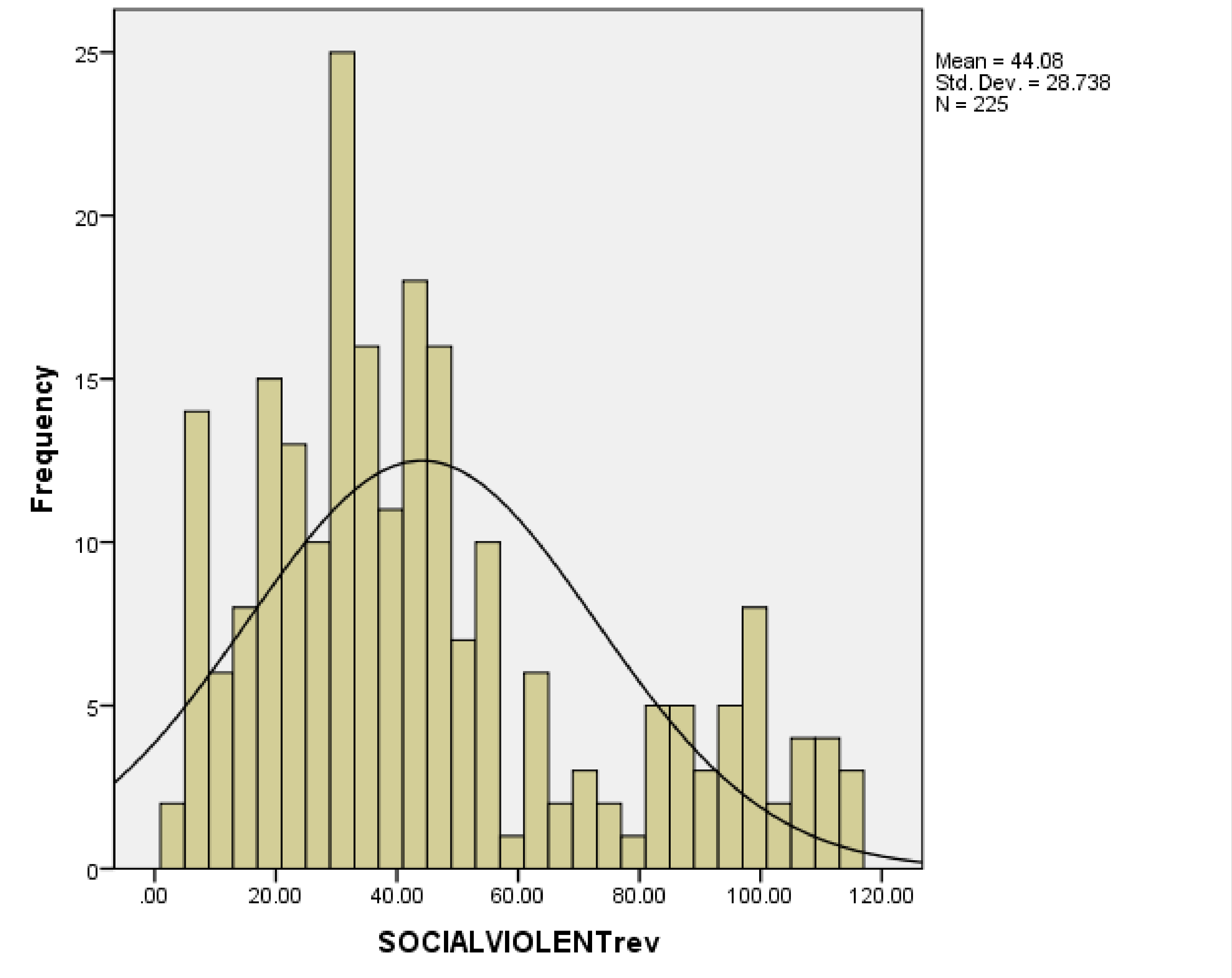
	SEX	N	Mean Rank		
WarmingBurning (rev)	MALE	78	104.28	Chi-Square	2.147
	FEMALE	147	117.63	df	1
	Total	225		Asymp. Sig.	0.143
	BURNTORNOT	N	Mean Rank		
WarmingBurning (rev)	No	46	105.37	Chi-Square	0.795
	Yes	179	114.96	df	1
	Total	225		Asymp. Sig.	0.373
	PARENTHOOD	N	Mean Rank		
WarmingBurning (rev)	NO	41	95.18	Chi-Square	3.760
	YES	184	116.97	df	1
	Total			Asymp. Sig.	0.053

	NewAge	N	Mean Rank		
WarmingBurning (rev)	18-24	75	108.41		
	25-34	67	112.11	Chi-Square	4.748
	35-44	38	102.88	Df	5
	45-54	23	126.93	Asymp. Sig.	0.447
	55-64	14	132.11		
	65+	8	138.00		
	Total	225			
	Smokingstatus	N	Mean Rank		
WarmingBurning (rev)	never smoked	55	121.97	Chi-Square	1.482
	ex-smoker	66	108.14	Df	2
	current smoker	104	111.34	Asymp. Sig.	0.477
	Total	225			

Table 6.21: Kruskal-Wallis test data with WarmingBurning(rev) as the test variable and a number of grouping variables

SocialViolent (rev)

Figure 6.39: A histogram of the frequency of responses from the Batwa cohort to SocialViolent(rev)



A mean of 44.08 (St. Dev. 28.738) and a median of 37.0 shows that fire is seen as more social than violent despite the fact that ~80% of Batwa responded that they had been previously burnt (Table 6.16). Trends within data are very evident (Fig. 6.39) and can be classed broadly as bi-modally distributed. The largest mode (range 5-50) contains the majority of all of the data points and shows that the strength of the preference for social is broad and strong. Very few participants responded in the range 60-80 (fire is both social and violent but the balance is slightly in favour of violent). A smaller 'highly-violent' mode in the range of 80-120 exists, populated by respondents who thought that fire was much more violent than social. Kruskal-Wallis testing did not identify any statistically significant relationships (Table. 6.22) and only the variable 'burnt-or-not' showed any really noticeable differences in responses (χ^2 = 2.243, p = 0.134).

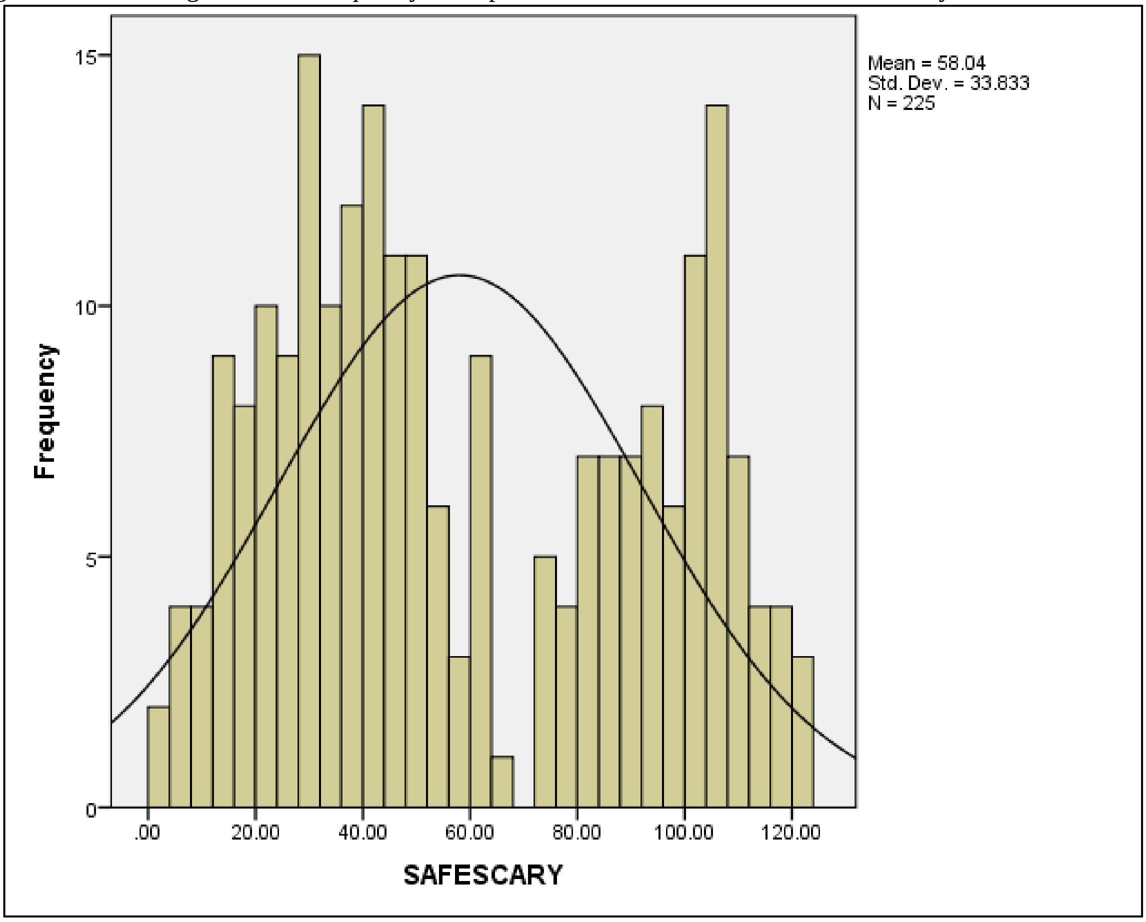
	SEX	N	Mean Rank		
SocialViolent (rev)	MALE	78	110.20	Chi-Square	0.221
	FEMALE	147	114.49	df	1
	Total	225		Asymp. Sig.	0.638
	BURNTORNOT	N	Mean Rank		
SocialViolent (rev)	No	46	100.18	Chi-Square	2.243
	Yes	179	116.29	df	1
	Total	225		Asymp. Sig.	0.134
	PARENTHOOD	N	Mean Rank		
SocialViolent (rev)	NO	41	111.20	Chi-Square	0.039
	YES	184	113.40	df	1
	Total			Asymp. Sig.	0.844
	NewAge	N	Mean Rank		
SocialViolent (rev)	18-24	75	112.19		
	25-34	67	112.06	Chi-Square	0.649
	35-44	38	115.29	df	5
	45-54	23	118.91	Asymp. Sig.	0.986
	55-64	14	102.93		
	65+	8	118.19		
	Total	225			
	Smokingstatus	N	Mean Rank		
SocialViolent (rev)	never smoked	55	117.10	Chi-Square	1.361
	ex-smoker	66	105.19	df	2
	current smoker	104	115.79	Asymp. Sig.	0.506
	Total	225			

Table 6.22: Kruskal-Wallis test data with SocialViolent(rev) as the test variable and a number of grouping variables

SafeScary

A mean of 58.04 (St. Dev. 33.833) and a median of 48.0 shows that fire is perceived as more safe than scary by the Batwa. The large difference between the mean and median values is explainable by the very strongly bi-modal distribution (Fig. 6.40). One mode is in the 'safe' spectrum (0-50) while the other is in the 'scary' spectrum (80-120). The range of 50-80 lies between the two modes and has very few data points within it showing that this was a question that really divided opinion with few respondents thinking that fire was both safe and scary; perhaps this is down to the fact that of all the word-pairs this pair contains two quite polar concepts. On a positive note the nature of the responses to this word-pair highlights the nuanced understanding the Batwa had of how to respond to this innovative and previously unseen research methodology and thus further strengthens conclusions drawn

Figure 6.40: A histogram of the frequency of responses from the Batwa cohort to SafeScary



from the responses of the Batwa cohort. Kruskal-Wallis testing did not identify any statistically significant relationships (Table. 6.23) and only the variable 'age' showed any real differences in responses ($\chi^2 = 8.374$, $p = 0.137$); with the three younger age groups (18-24, 25-34, 35-44) finding fire to be more safe and less scary than older age groups (Table 6.23).

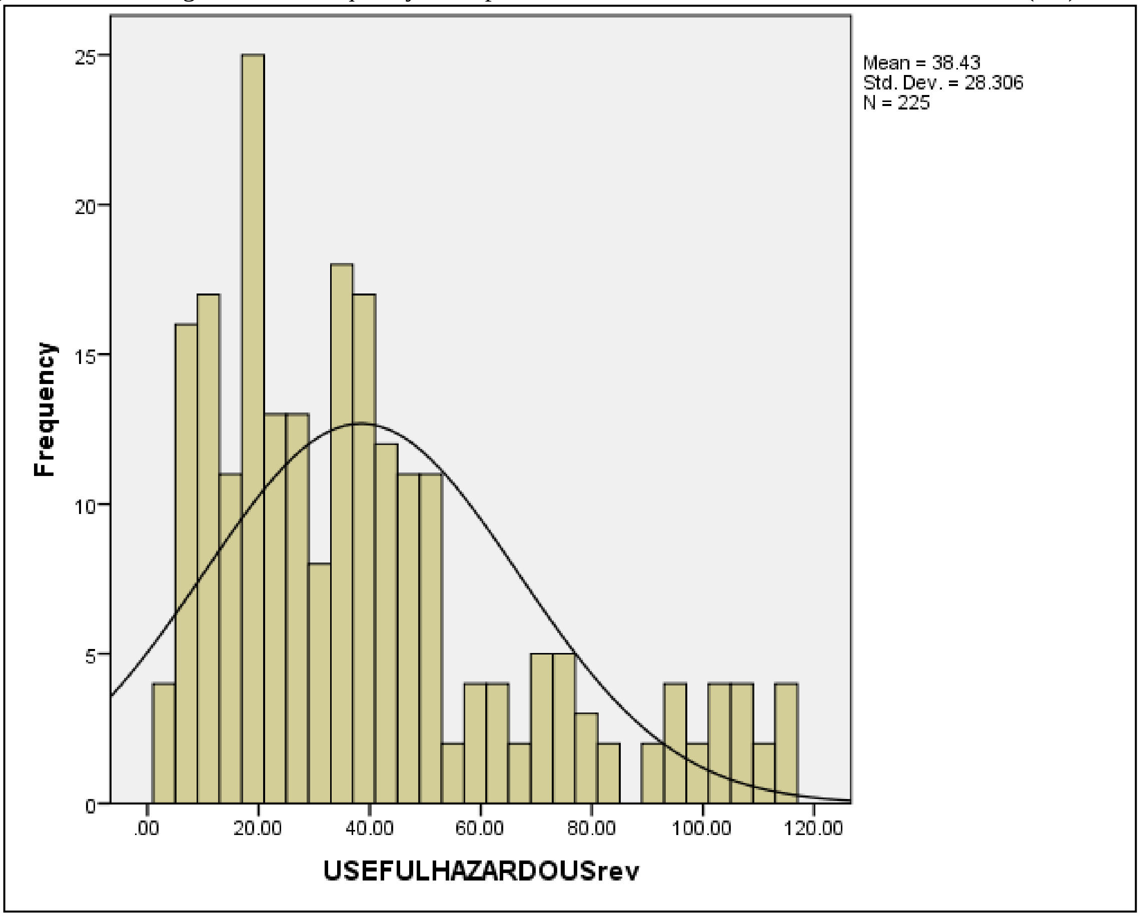
	SEX	N	Mean Rank		
SafeScary	MALE	78	116.63	Chi-Square	0.371
	FEMALE	147	111.07	df	1
	Total	225		Asymp. Sig.	0.542
	BURNTORNOT	N	Mean Rank		
SafeScary	no	46	101.68	Chi-Square	1.941
	yes	179	116.06	df	1
	Total	225		Asymp. Sig.	0.164
	PARENTHOOD	N	Mean Rank		
SafeScary	NO	41	102.29	Chi-Square	1.357
	YES	184	115.39	df	1
	Total			Asymp. Sig.	0.244
	NewAge	N	Mean Rank		
SafeScary	18-24	75	118.10		
	25-34	67	107.78	Chi-Square	8.374
	35-44	38	92.03	df	5
	45-54	23	123.67	Asymp. Sig.	0.137
	55-64	14	134.96		
	65+	8	139.44		
	Total	225			
	Smokingstatus	N	Mean Rank		
SafeScary	never smoked	55	110.74	Chi-Square	0.892
	ex-smoker	66	119.35	df	2
	current smoker	104	110.17	Asymp. Sig.	0.640
	Total	225			

Table 6.23: Kruskal-Wallis test data with SafeScary as the test variable and a number of grouping variables

UsefulHazardous (rev)

A mean of 38.431 (St. Dev. 28.306) and a median of 33.0 was identified. This shows that for the Batwa cohort fire is viewed as much more useful than hazardous; a visually evident relationship (Fig. 6.41). Of the eleven word-pairs in question one this pair had the most 'positive' response from the Batwa cohort and also both the lowest mean and median values. This is perhaps not surprising given the importance that fire plays within Batwa culture and ritual behaviour (confirmed by oral testimony collected as part of this study) and the breadth of fire-uses that the Batwa responded that they had. Most Batwa that we asked knew how to make fire from sticks, which sticks to use and where to find them[15] (Note: this was not part of the official questionnaire but was given to respondents who were inquisitive about the research and were keen to chat some more).

Figure 6.41: A histogram of the frequency of responses from the Batwa cohort to UsefulHazardous(rev)

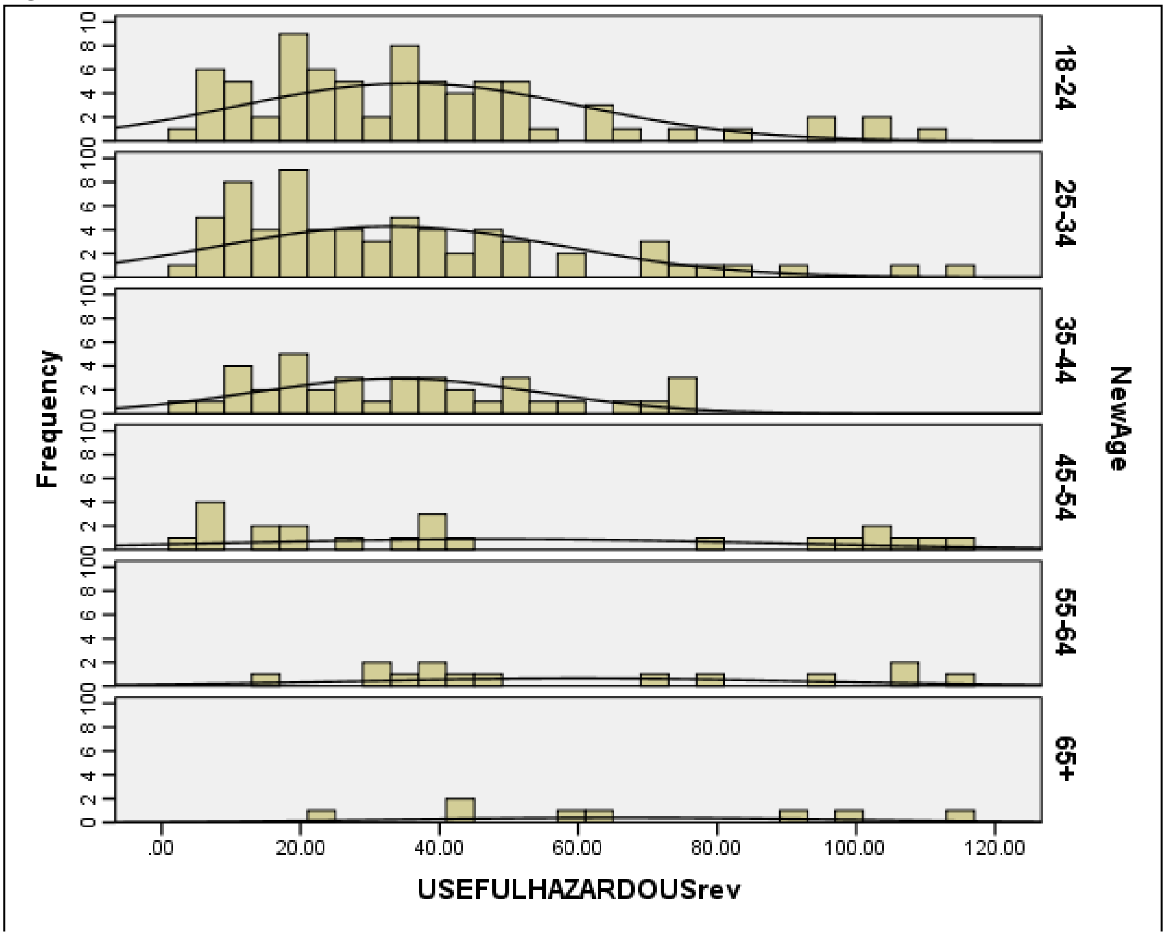


Within the data a very prominent mode in the 0-50 range demonstrates that while the majority of Batwa think fire is more useful than hazardous the strength of this feeling is spread across a broad spectrum with the largest peak in the 20-30 range (people who think fire is a bit hazardous but considerably more useful). Within the range of 50-120 responses

[15] As a quick aside it is interesting to note that on a day the research team spent in the forest with three experienced male Batwa looking for wild honey and trying to observe and learn about traditional Batwa culture and life-ways a 'traditional fire-making contest' was held with competitors comprising three male Batwa guides and two researchers. Mr Niwagaba Christopher, a Muciga logistician and translator, had a fire going more than ten minutes faster than any Batwa and won the grand prize - a large bag of dried mango

are fairly uniformly spread showing that some people did differ from mainstream Batwa thinking. Kruskal-Wallis testing did identify one statistically significant relationship, ‘age’ (χ^2 = 16.348, p = 0.006) (Table. 6.24; Fig. 6.42).

Figure 6.42: A histogram of the frequency of responses from the Batwa cohort to UsefulHazardous(rev) filtered by age



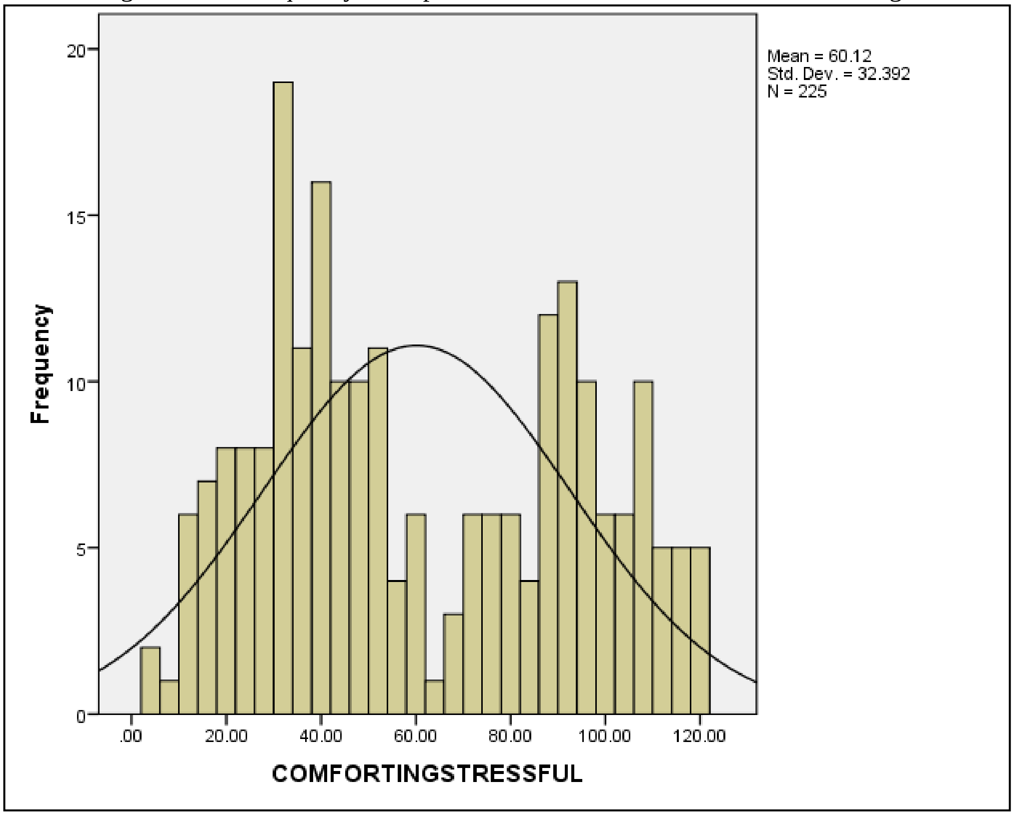
Once again the three younger age groups (encompassing the ages of 18-44) answered most positively about fire (Fig. 6.42); older age groups contained more people who viewed fire as hazardous. This may be as a result of reduced mobility (not able to run aware from ‘hazardous fires’ so easily), broader life experience, changing perceptions of risk as one gets older or perhaps some other reason entirely. Interestingly, within the age group 35-44 (N = 38) not a single respondent gave a score higher than 75, showing that none of this group thought fire was much more hazardous than useful (Fig. 6.42).

	SEX	N	Mean Rank		
UsefulHazardous (rev)	MALE	78	112.25	Chi-Square	0.016
	FEMALE	147	113.40	Df	1
	Total	225		Asymp. Sig.	0.900
	BURNTORNOT	N	Mean Rank		
UsefulHazardous (rev)	no	46	99.83	Chi-Square	2.371
	yes	179	116.39	Df	1
	Total	225		Asymp. Sig.	0.124
	PARENTHOOD	N	Mean Rank		
UsefulHazardous (rev)	NO	41	112.57	Chi-Square	0.002
	YES	184	113.10	Df	1
	Total			Asymp. Sig.	0.963
	NewAge	N	Mean Rank		
UsefulHazardous (rev)	18-24	75	110.09		
	25-34	67	100.66	Chi-Square	16.348
	35-44	38	107.84	Df	5
	45-54	23	119.00	Asymp. Sig.	0.006
	55-64	14	157.68		
	65+	8	172.75		
	Total	225			
	Smokingstatus	N	Mean Rank		
UsefulHazardous (rev)	never smoked	55	108.06	Chi-Square	1.173
	ex-smoker	66	109.16	Df	2
	current smoker	104	118.05	Asymp. Sig.	0.556
	Total	225			

Table 6.24: Kruskal-Wallis test data with UsefulHazardous(rev) as the test variable and a number of grouping variables

ComfortingStressful

Figure 6.43: A histogram of the frequency of responses from the Batwa cohort to ComfortingStressful



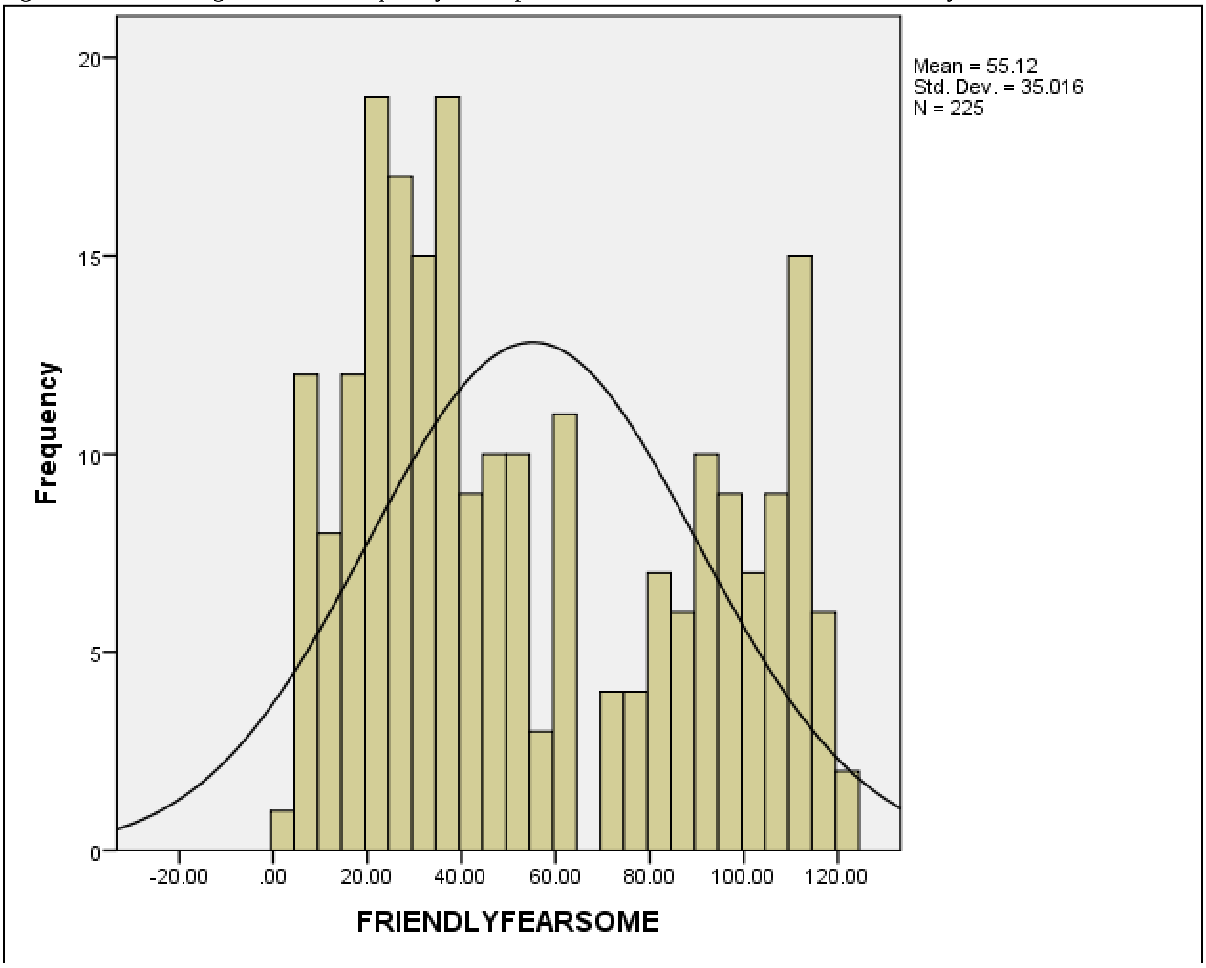
A mean of 60.12 (St. Dev. 32.392) and a median of 50 shows that within the Batwa mind-set fire is seen as both comforting and stressful (Fig. 6.43). A mean of ~60 suggests that this balance is roughly equal but the Median of 50 shows that those who view fire as stressful have a greater strength of feeling on the subject than those who think of fire as comforting. ComfortingStressful is probably one of the word-pairings that could be described as being 'highly dichotomous'. Data is very much a bi-modally distributed; one large mode for those who view fire as more comforting and one for those who view fire as more stressful. Interestingly the range that denotes an equal or almost equal strength of feeling on the subject (50-70) is quite sparsely populated. This again points to the strength of understanding the Batwa had of the interview methods as while fire can be both comforting and stressful; it may be expected that those people who have a lot of contact with fire will have a clear preference between the two concepts. Kruskal-Wallis testing identified no significant relationships with any of the demographic variables (Table. 6.25).

	SEX	N	Mean Rank		
ComfortingStressful	MALE	78	119.75	Chi-Square	1.285
	FEMALE	147	109.42	df	1
	Total	225		Asymp. Sig.	0.257
	BURNTORNOT	N	Mean Rank		
ComfortingStressful	no	46	115.41	Chi-Square	0.080
	yes	179	112.38	df	1
	Total	225		Asymp. Sig.	0.778
	PARENTHOOD	N	Mean Rank		
ComfortingStressful	NO	41	123.29	Chi-Square	1.254
	YES	184	110.71	df	1
	Total			Asymp. Sig.	0.263
	NewAge	N	Mean Rank		
ComfortingStressful	18-24	75	121.49		
	25-34	67	111.33	Chi-Square	4.291
	35-44	38	105.14	df	5
	45-54	23	94.15	Asymp. Sig.	0.508
	55-64	14	120.75		
	65+	8	125.38		
	Total	225			
	Smokingstatus	N	Mean Rank		
ComfortingStressful	never smoked	55	125.62	Chi-Square	2.807
	ex-smoker	66	110.58	df	2
	current smoker	104	107.87	Asymp. Sig.	0.246
	Total	225			

Table 6.25: Kruskal-Wallis test data with ComfortingStressful as the test variable and a number of demographic grouping variables

FriendlyFearsome

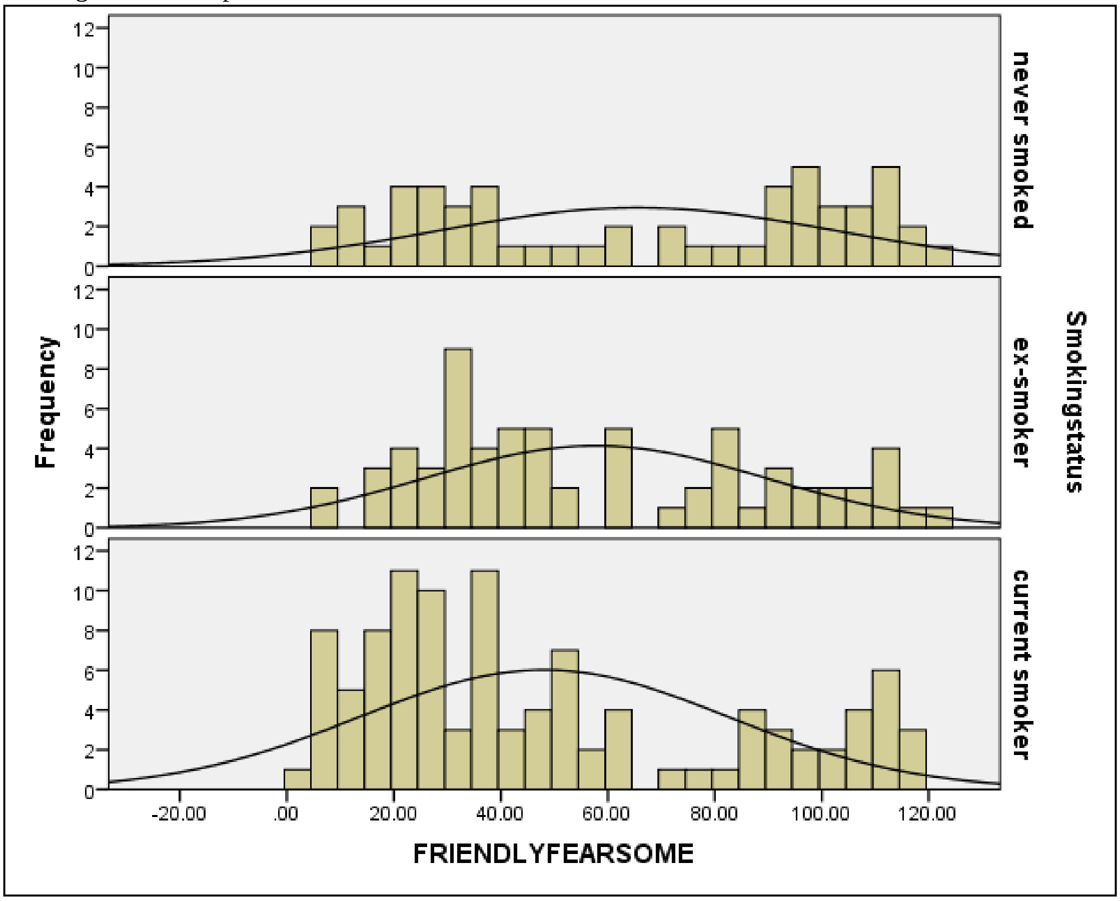
Figure 6.44: A histogram of the frequency of responses from the Batwa cohort to FriendlyFearsome



The mean was 55.124 (St. Dev. 35.016) and the median was 46.0 and the distribution was bimodal. A very prominent mode exists in the range 15-40 denoting those respondents who thought fire was highly friendly and not very fearsome at all (Fig. 6.44). The other prominent mode (range 70-110) represents those participants who thought fire was very fearsome and not very friendly at all. Again, interestingly, very few people responded that they thought fire was roughly equally friendly and fearsome. The relatively large difference between the mean and median values, allied with trends within Fig. 6.44, suggests that overall the Batwa viewed fire as more much friendly than fearsome, but that those who view fire as fearsome strongly hold this view.

Kruskal-Wallis testing identified one strong statistically significant relationship between the Batwa responses to friendlyfearsome and the smoking status of individuals ($\chi^2 = 9.210$, p = 0.010) (Fig. 6.45, Table. 6.26). Current smokers thought that fire was friendlier and less fearsome than ex-smokers who in turn thought fire was friendlier and less fearsome than never-smokers. Many current smokers classified fire as ‘very friendly and hardly fearsome at all’. This again supports the notion that those who use fire a lot have a very positive Landscape of Fear around fire; a mind-set that is perhaps necessary so as to be able to fully benefit from fires’ attributes.

Figure 6.45: A histogram of the frequency of responses from the Batwa cohort to FriendlyFearsome filtered by the smoking status of respondents



	SEX	N	Mean Rank		
FriendlyFearsome	MALE	78	107.69	Chi-Square	0.796
	FEMALE	147	115.82	Df	1
	Total	225		Asymp. Sig.	0.372
	BURNTORNOT	N	Mean Rank		
FriendlyFearsome	No	46	118.77	Chi-Square	0.455
	Yes	179	111.52	Df	1
	Total	225		Asymp. Sig.	0.500

	PARENTHOOD	N	Mean Rank		
FriendlyFearsome	NO	41	111.71	Chi-Square	0.20
	YES	184	113.29	Df	1
	Total			Asymp. Sig.	0.888
	NewAge	N	Mean Rank		
FriendlyFearsome	18-24	75	110.47		
	25-34	67	114.05	Chi-Square	3.707
	35-44	38	101.58	Df	5
	45-54	23	126.43	Asymp. Sig.	0.592
	55-64	14	133.39		
	65+	8	107.88		
	Total	225			
	Smokingstatus	N	Mean Rank		
FriendlyFearsome	never smoked	55	129.64	Chi-Square	9.210
	ex-smoker	66	120.83	Df	2
	current smoker	104	99.23	Asymp. Sig.	0.010
	Total	225			

Table 6.26: Kruskal-Wallis test data with FriendlyFearsome as the test variable and a number of demographic grouping variables

GiftThreat

The mean was 55.440 (St. Dev. 34.366) and the median was 48.0 showing that the Batwa think of fire as more of a gift than a threat. Results are broadly bi-modally distributed. A very prominent mode exists in the range 15-30 denoting respondents who thought fire was very much a gift and hardly a threat at all (Fig. 6.46). A second, smaller, mode denotes people who perceive fire as very much a threat and not much of a gift at all (range 100-120). Kruskal-Wallis testing identified that the smoking status of a respondent was statistically significant (X2 = 8.976, p = 0.011) (Table. 6.27). While never-smokers were quite balanced in their responses (a bimodal distribution with populations spread relatively proportionally across the spectrum), ex-smokers were more in favour of fire as a gift; in turn current smokers were very much more likely to view fire as a gift with the prominent mode in the 15-30 range (Fig. 6.46) largely being made up of current smokers (Fig. 6.47). This again provides good evidence that those people who are most in contact with fire view fire very much more positively than those who have less contact. Within the context of this study, this is a very important point to consider when attempting to study, model and illuminate the earliest ancestral relationships with fire.

Figure 6.46: A histogram of the frequency of responses from the Batwa cohort to GiftThreat

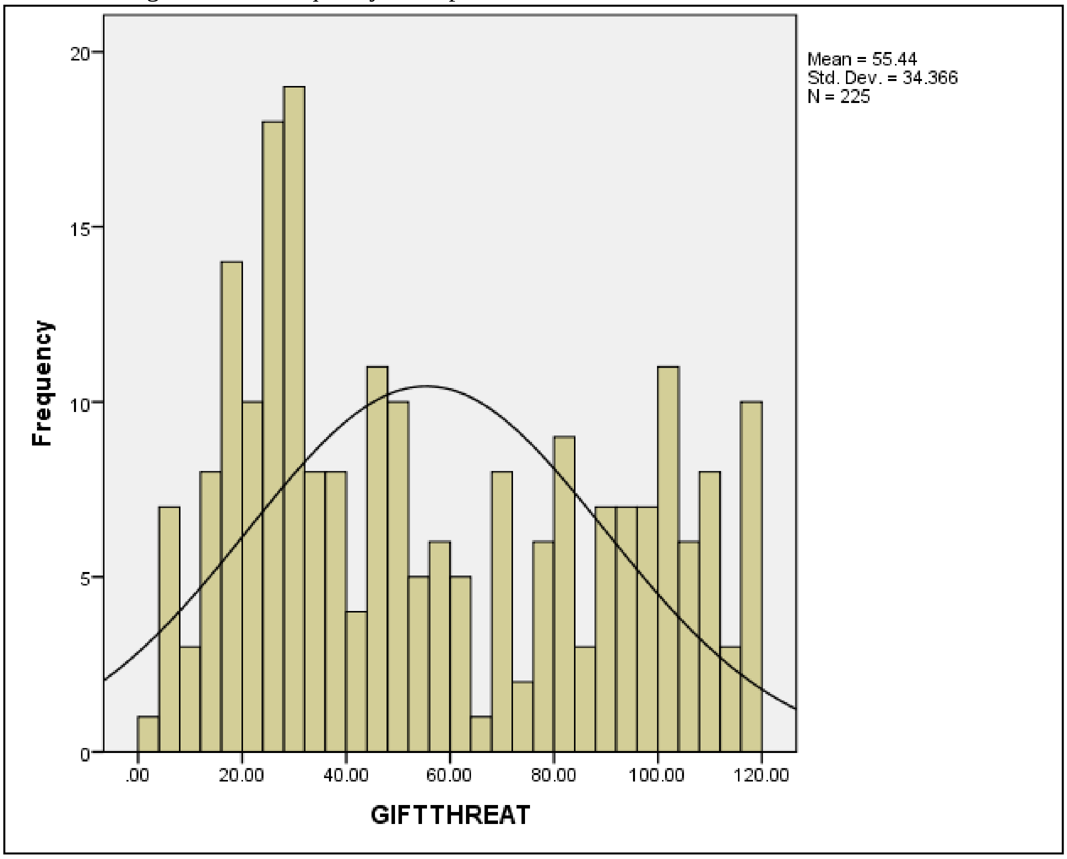
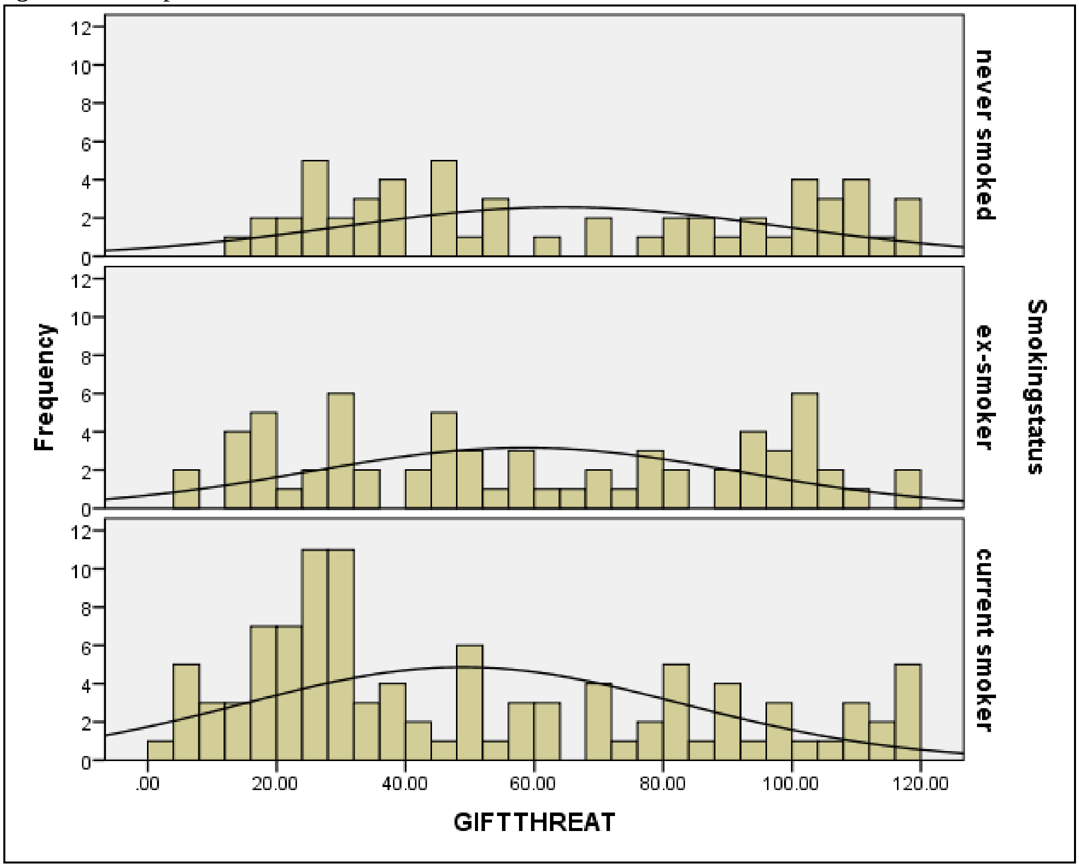


Figure 6.47: A histogram of the frequency of responses from the Batwa cohort to GiftThreat filtered by the smoking status of respondents



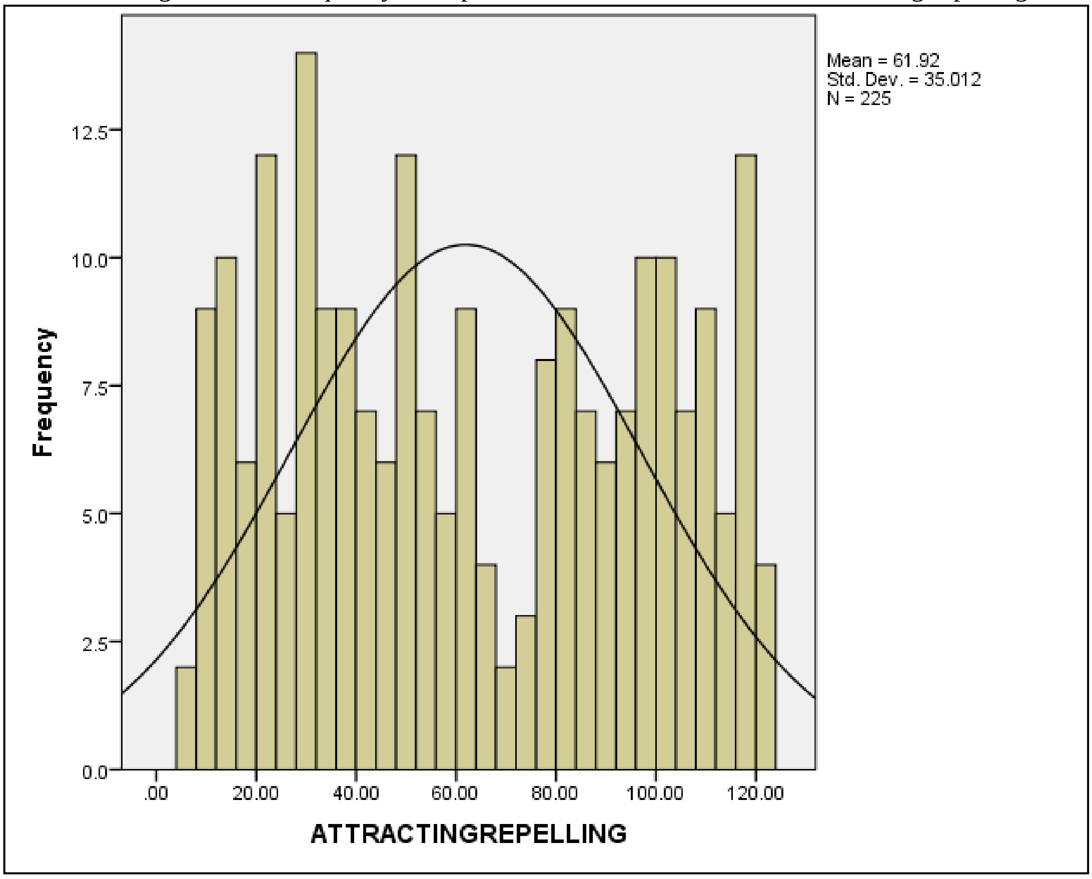
	SEX	N	Mean Rank		
GiftThreat	MALE	78	104.12	Chi-Square	2.223
	FEMALE	147	117.71	Df	1
	Total	225		Asymp. Sig.	0.136
	BURNTORNOT	N	Mean Rank		
GiftThreat	No	46	118.25	Chi-Square	0.376
	Yes	179	111.65	Df	1
	Total	225		Asymp. Sig.	0.540
	PARENTHOOD	N	Mean Rank		
GiftThreat	NO	41	99.88	Chi-Square	2.039
	YES	184	115.92	Df	1
	Total			Asymp. Sig.	0.153
	NewAge	N	Mean Rank		
GiftThreat	18-24	75	107.74		
	25-34	67	114.73	Chi-Square	4.216
	35-44	38	107.76	Df	5
	45-54	23	134.50	Asymp. Sig.	0.519
	55-64	14	102.18		
	65+	8	129.81		
	Total	225			
	Smokingstatus	N	Mean Rank		
GiftThreat	never smoked	55	131.07	Chi-Square	8.976
	ex-smoker	66	118.64	Df	2
	current smoker	104	99.87	Asymp. Sig.	0.011
	Total	225			

Table 6.27: Kruskal-Wallis test data with GiftThreat as the test variable and a number of demographic grouping variables

AttractingRepelling

Data is broadly bi-modally distributed with a mean of 61.920 (St. Dev. 35.012) and a median of 58.0. Results suggest that the Batwa view fire as very much both attracting and repelling in almost equal proportions (Fig. 6.48). This was a question that really split opinion with many responses from participants grouping in both the 5-40 and 80-115 ranges suggesting the presence of strong feeling in both directions; very few respondents ‘sat on the fence’. Because of the spread of data it would have been very informative had Kruskal-Wallis testing identified any statistically significant relationships; unfortunately this was not the case (Table. 6.28). The only supported conclusion to be drawn is that the attractive and repelling forces of fire are both strongly represented within Batwa LOFs. The Batwa can be considered to be equally mindful of both the positive and negative capacity of fire.

Figure 6.48: A histogram of the frequency of responses from the Batwa cohort to AttractingRepelling



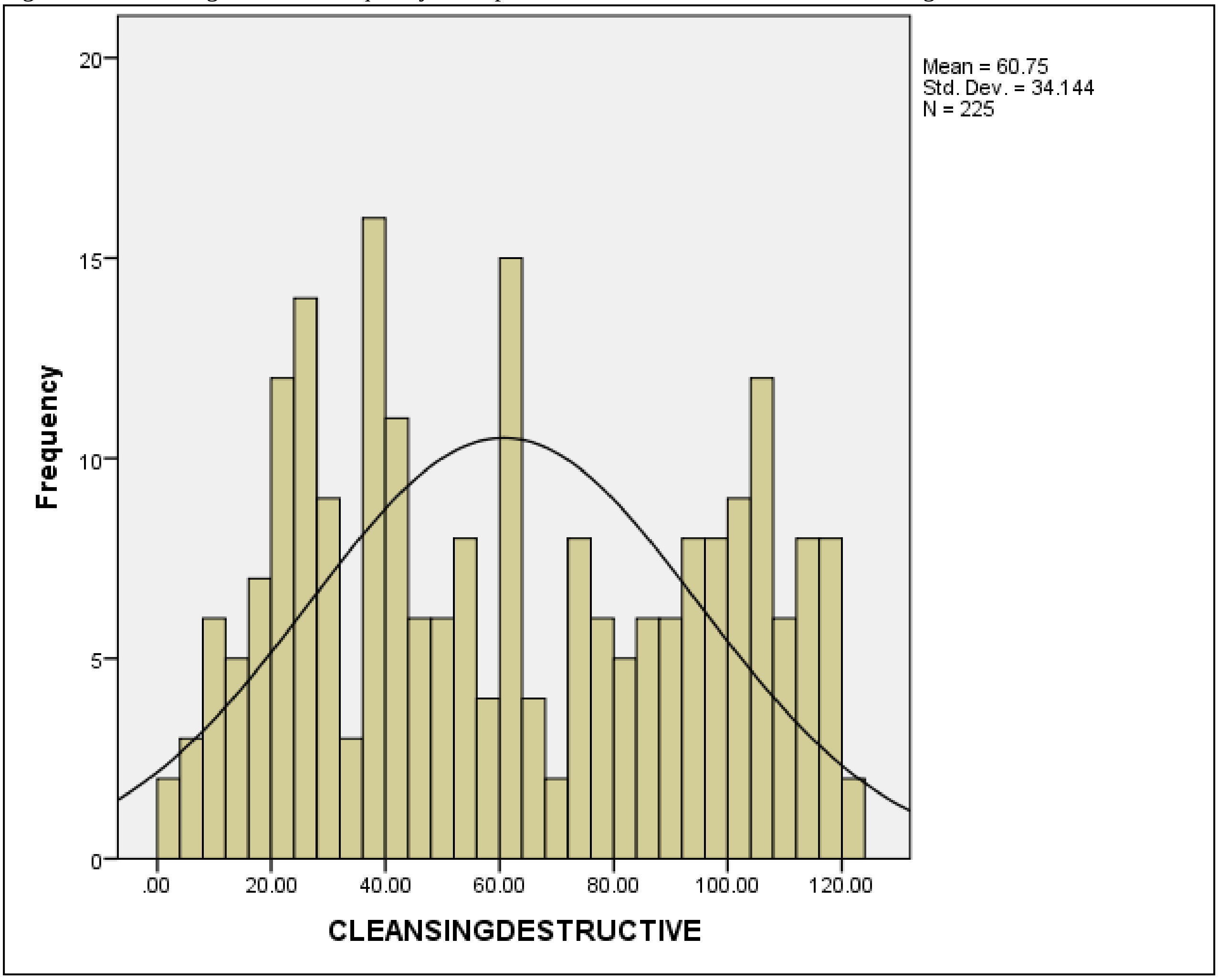
	SEX	N	Mean Rank		
AttractingRepelling	MALE	78	106.62	Chi-Square	1.149
	FEMALE	147	116.39	Df	1
	Total	225		Asymp. Sig.	0.284
	BURNTORNOT	N	Mean Rank		
AttractingRepelling	no	46	103.62	Chi-Square	1.201
	yes	179	115.41	Df	1
	Total	225		Asymp. Sig.	0.273
	PARENTHOOD	N	Mean Rank		
AttractingRepelling	NO	41	112.09	Chi-Square	0.010
	YES	184	113.20	Df	1
	Total			Asymp. Sig.	0.921
	NewAge	N	Mean Rank		
AttractingRepelling	18-24	75	118.50		
	25-34	67	114.45	Chi-Square	3.087
	35-44	38	102.20	Df	5
	45-54	23	116.83	Asymp. Sig.	0.687
	55-64	14	93.93		
	65+	8	123.00		
	Total	225			
	Smokingstatus	N	Mean Rank		
AttractingRepelling	never smoked	55	119.14	Chi-Square	0.656
	ex-smoker	66	111.59	Df	2
	current smoker	104	110.65	Asymp. Sig.	0.720
	Total	225			

Table 6.28: Kruskal-Wallis test data with AttractingRepelling as the test variable and a number of demographic grouping variables

CleansingDestructive

The mean was 60.747 (St. Dev. 34.144) and the median 60.0; data is multimodal (Fig. 6.49) suggesting that the Batwa view fire as very much capable of being both a cleansing and a destructive force. One identifiable mode is in the 15-30 range denoting those people who perceive fire as highly cleansing and hardly destructive at all. Another mode occupies the narrow 35-45 range denoting those who think fire is more cleansing than destructive but not with such strength of feeling as those respondents who occupy the first mode. A third mode is a very broad mode in the 70-115 range. This mode is made up of people who believe that fire is more destructive than cleansing; a wide spectrum of strength of views exists within the occupants of this mode.

Figure 6.49: A histogram of the frequency of responses from the Batwa cohort to CleansingDestructive



Due to the spread of data it would have been very informative had Kruskal-Wallis testing identified any statistically significant relationships; unfortunately this was not the case (Table. 6.29), so the only conclusion to be drawn is that fire is both cleansing and destructive in the eyes of the Batwa. None of the demographic information collected is able to shed light on the reasons that some of the Batwa think x and some think y. Respondents within the two oldest age groups seemed to perceive that fire was more cleansing than younger participants but this relationship is not significant at all (χ^2 = 1.706, p = 0.888) (Table. 6.29).

	SEX	N	Mean Rank		
CleansingDestructive	MALE	78	112.96	Chi-Square	0.000
	FEMALE	147	113.02	df	1
	Total	225		Asymp. Sig.	0.995
	BURNTORNOT	N	Mean Rank		
CleansingDestructive	No	46	106.41	Chi-Square	0.593
	Yes	179	114.69	df	1
	Total	225		Asymp. Sig.	0.441
	PARENTHOOD	N	Mean Rank		
CleansingDestructive	NO	41	112.02	Chi-Square	0.011
	YES	184	113.22	df	1
	Total			Asymp. Sig.	0.915
	NewAge	N	Mean Rank		
CleansingDestructive	18-24	75	115.63		
	25-34	67	117.75	Chi-Square	1.706
	35-44	38	105.79	df	5
	45-54	23	113.98	Asymp. Sig.	0.888
	55-64	14	99.96		
	65+	8	102.88		
	Total	225			
	Smokingstatus	N	Mean Rank		
CleansingDestructive	never smoked	55	122.63	Chi-Square	2.176
	ex-smoker	66	114.67	df	2
	current smoker	104	106.85	Asymp. Sig.	0.337
	Total	225			

Table 6.29: Kruskal-Wallis test data with CleansingDestructive as the test variable and a number of demographic grouping variables

Batwa Summary

None of the datasets generated by the Batwa cohort conformed to what would be expected from a normal distribution. Age and smoking status were both found to have three statistically significant relationships each. ProtectiveRisky (rev) was observed to have the most number of statistically significant relationships computed from the five grouping variables tested for with two significant relationships (both ‘Age’ and ‘Smoking Status’); ExcitingDangerous, UsefulHazardous(rev), FriendlyFearsome and GiftThreat were all found to have one statistically significant relationships (either ‘Age’ or ‘Smoking Status’); (Table. 6.30). The other six word-pairs were all found to have zero statistically significant relationships. Interestingly the four variables which had a mean greater than 56.00 coupled with a median greater than 47.0 (Table 6.18) all had no statistically significant relationships with any of the word-pairs. Seemingly the ‘less-balanced’ responses from the Batwa cohort (those with averages more distal from 60) were more likely to have statistically significant relationships with which to explain observed results and trends.

Due to issues with the nature of Batwa lifestyles, available technologies and strongly predominantly rural distribution (discussed earlier) only five demographic variables (rather than the nine possible for the UK cohort) could be tested for significance. Of the five tested for, three were observed to have no significance within the responses to the word-pairs in Q1 (sex, whether a respondent had been previously burnt or not and whether a participant was a parent or not). No statistically significant relationships with ‘burnt or not’ was not too much of a surprise to researchers as 179 out of 225 (79.6%) Batwa reported that they had previously been burnt (mean strength of burn = 49.33, ST. Dev = 33.655, median = 38.0) meaning that only 20.4% had never been burnt. Perhaps this imbalance in proportions between those who had and had not been burnt was too great to be able to find statistically significant relationships that may have been present were the ratio to have been 50/50, or 60/40 rather than 80/20. Parenthood also suffered with the same ~80/20 ratio (81/19) which may also help explain the lack of statistically significant relationships.

Variable	Number of statistically significant relationships					
	Sex	Burnt Or Not	Parenthood	New Age	Smoking Status	TOTAL
PROTECTIVERISKY(rev)	N	N	N	Y	Y	2
EXCITINGDANGEROUS	N	N	N	Y	N	1
WARMINGBURNING(rev)	N	N	N	N	N	0
SOCIALVIOLENT(rev)	N	N	N	N	N	0
SAFESCARY	N	N	N	N	N	0
USEFULHAZARDOUS(rev)	N	N	N	Y	N	1
COMFORTINGSTRESSFUL	N	N	N	N	N	0
FRIENDLYFEARSOME	N	N	N	N	Y	1
GIFTTHREAT	N	N	N	N	Y	1
ATTRACTINGREPELLING	N	N	N	N	N	0
CLEANSINGDESTRUCTIVE	N	N	N	N	N	0
TOTAL	0	0	0	3	3	

Table 6.30: A summary of the number of statistically significant relationships obtained by Kruskal-Wallis testing data collected from the Batwa cohort (95% confidence level)

The gender split however was 65/35 which should not present the same statistical issues as the less balanced ratios discussed previously. The conclusion to come to with the Batwa is that, with regard to gender, there really was no statistically significance between the responses provided by males and females; this differs from the four statistically significant relationships observed within the UK cohort (Table 6.15). The Batwa are locally known to be a relatively highly egalitarian society; perhaps this egalitarianism has allowed the collective Batwa mindset or Landscape of Fear to develop without gender differences. The Batwa appear to have incorporated into their Landscape of Fear, and framing of fire, mindfulness of both the positive and negative capacity of fire.

C3 – The Non-Batwa African Cohort (NBA)

Frequencies

Category	Variable	NBA
	N	219
		%
Sex	Male	69.4
	Female	30.6
Parenthood	No children	79.0
	Children under age 18	18.3
	Adult children	2.7
New Age	18-24	64.8
	25-34	23.7
	35-44	6.8
	45-54	2.7
	55-64	0.9
	65+	0.9
Smoking status	Never smoked	85.8
	Ex-smoker	9.6
	Current smoker	4.6
Burnt or not	No	22.4
	Yes	77.6
How badly burnt	Numbers burnt **(not %)**	N = 170
This data only looks at those who answered that they had been burnt	Slightly	60.7
	Moderately	10.0
	Severely	6.8
Fire-uses individual (% yes)	Keeping insects away	61.6
	Cooking food	100
	Keeping warm	90.4
	Lighting	95.4
	Signalling	34.7
	Cleaning and cleansing	47.0
	Boiling water	99.1
	Killing plants	62.1
	Burning rubbish	97.7
	Making things	62.6
Fire usage combined	Low Usage (1-3)	1.8
	Medium Usage (4-6)	27.9
	High Usage (7-10)	70.3
Under 10 living environment (predominant)	Rural	72.6
	Urban	27.4
Age 10 to 18 living environment (predominant)	Rural	49.3
	Urban	50.7
Current living environment	Rural	26.0
	Urban	74.0

Table 6:31: Frequencies of certain demographic descriptors from the NBA sample (N=219)

Once the data had been input into SPSS and the analysis begun it quickly became apparent that the demographic makeup of the Non-Batwa African (NBA) cohort was markedly different to both the UK (table 6.1) and the Batwa (table 6.15) populations. These differences are visible in every single variable displayed in Tables 6.1, 6.16 and 6.31. The population pyramid is very much more like an extreme ‘lesser developed country’ than the Batwa and very different indeed to the UK population due in part to the predominance of students from Kabale University (this is despite many of the UK cohort being directly recruited on the University of Liverpool campus). The gender split is almost the reverse of the Batwa; with the NBA cohort being very male dominated (Table 6.31). Many more NBAs had yet to produce children than either of the other two cohorts in this study. Additionally many more of the NBA cohort had never smoked than was observed within the UK or Batwa cohorts.

Roughly the same proportion of the NBA had been previously burnt as the Batwa (both of which had much higher frequencies of being burnt than the UK cohort), but many more of the Batwa had been moderately or severely burnt than NBAs (however as this was self-assessed perhaps more research is needed on how ‘dramatic’ the different populations are when it comes to self-assessing the extent of their injuries). The NBA cohort had a breadth of fire-use experience significantly greater than the UK population (e.g. high usage 70.3% compared to 25.3%) but much less than the Batwa, entirely in line with ‘pre-data collection’ expectations. The data on ‘under 10’, ‘adolescent’ and ‘current living environments’ was also very different to both the UK and Batwa populations but was again in line with ‘pre-data collection expectations’ (although the urbanisation trend visible is much more clear than previously expected).

Table 6.31 shows the demographic frequencies and responses to some key variables from the NBA cohort. Of the 219 people recruited to make up the NBA cohort 152 (69.4%) were male and 67 (30.6%) were female. This gender imbalance may be an artefact of the twin facts that the majority of the NBA sample comes from the campus of Kabale University (N=176) where not only were males vastly more prevalent, they were also more approachable to the research team (despite the highly eloquent communication skills of logistician and translator Mr Jimmy Brown). In the other locations where NBA data collection occurred males vastly outnumbered females; this is perhaps down to educational and employment opportunities or other cultural differences inherent within the NBA communities surveyed. 173 people had no children (79.0%), 40 respondents said their youngest child was under the age of 18 (18.3%) and 6 people responded that their youngest child was 18+ (2.7%). 49 people stated that they had never been burnt (22.4%) while 170 stated that they had (77.6%) (mean = 25.62, St. Dev = 31.95). Of those who reported being burnt, 133 (78.2%) classified their most serious burn as 'slight' (1-40), 22 (12.9%) as 'moderately serious' (41-80) and 15 (8.8%) as 'severe' (81-120).188 people stated that they had never smoked (85.8%); this is predicted to be somewhat different to what the response would be from a UK university. 10 respondents were current smokers (4.6%) and 21 people classified themselves as ex-smokers (9.6%) (smoking data may be like this as Uganda has some of the strongest anti-smoking rhetoric and legislation in Africa and some of the toughest sanctions in the world).

The NBA sample, like that from the Batwa and UK populations, was placed into six different age groups (table 6.31). Nearly 90% of the NBA cohort were less than 35 years old; the largest age group was 18-24 (64.8%), the second largest was 25-34 (23.7%). 0.9% of the NBA cohort were each placed into the two oldest age groups (55-64 and 65+). The distribution therefore resembles an exaggerated population pyramid from a developing country with a baby boom and is much more of an ‘expansive pyramid’ shaped distribution than that produced from the Batwa cohort.

Data on the three ‘living environment’ variables in the NBA cohort is very interesting. This study managed to document a snapshot of the urbanisation process that has occurred in Africa over the past few decades. Analysis shows that of the NBA cohort 159 (72.6%) classified their ‘under 10 living environment as predominantly ‘rural’, while 60 (27.4%) classified as predominantly ‘urban’. This altered to 108 rural (49.3%) and 111 urban (50.7%) from ‘age 10 to age 18 living environment’. When questioned about their ‘current living environment’ 57 people classified as rural (26.0%) and 162 as urban (74%). This level of migration and movement highlights the very mobile nature of the NBA cohort. Even if the assumption is made that current living environment statistics are heavily influenced by the many students at Kabale University who live within university accommodation (situated on the fringes of an urban environment), the massive shift from a ~73/27 rural/urban ratio in under 10 living environment to the ~ 50/50 rural/urban ratio in the ‘Age 10 to 18 living environment’ is strong evidence of a recent major reorganisation of African society. That this was not seen in the Batwa data shows how unique the Batwa situation is, and how marginalised and disconnected they are from the societies and cultures in the midst of which they live.

Means

Analysis of the eleven word-pairings from section one of the questionnaire (ranging from 1-120) found that the responses within the population were diverse with the range of answers being between 117-119 (out of a possible 120) for every word-pairing. All of the standard deviations fell within the range of 27-38. It should be reiterated that these word-pairings were specifically chosen as NOT to be exact opposites of each other, but rather to allow respondents to choose between either a positive or negative emotion/connotation and find their own personal between.

	Range	Minimum	Maximum	Mean	Std. Error of Mean	Std. Dev.	Coefficient of Variance	Median
PROTECTIVERISKYrev	117.00	3.00	120.00	82.548	1.870	27.680	0.335	74.000
EXCITINGDANGEROUS	118.00	2.00	120.00	85.347	2.169	32.094	0.376	93.000
WARMINGBURNINGrev	117.00	3.00	120.00	73.283	1.911	28.273	0.386	66.000
SOCIALVIOLENTrev	118.00	1.00	119.00	70.406	2.531	37.462	0.532	71.000
SAFESCARY	118.00	2.00	120.00	75.959	2.461	36.418	0.479	84.000
USEFULHAZARDOUSrev	117.00	1.00	118.00	48.037	2.131	31.533	0.656	59.000
COMFORTINGSTRESSFUL	119.00	1.00	120.00	60.813	2.395	35.439	0.583	59.000
FRIENDLYFEARSOME	119.00	1.00	120.00	72.712	2.252	33.330	0.458	71.000
GIFTTHREAT	119.00	1.00	120.00	62.699	2.436	36.057	0.575	60.000
ATTRACTINGREPELLING	118.00	1.00	119.00	55.096	2.206	32.648	0.593	56.000
CLEANSINGDESTRUCTIVE	118.00	2.00	120.00	81.146	2.254	33.357	0.411	90.000

Table 6.32: Mean averages and related statistics for the NBA sample (N=219)

The data shows that the most ‘positive’ feeling about fire was ‘useful’ (from the ‘usefulhazardous’ word-pair – interestingly this was the same as with the Batwa) with a man of 48.037, while the most ‘negative’ was ‘dangerous’ with a mean of 85.347 (from the word-pair ‘excitingdangerous’). The word-pair that elicited on average the most balanced response was ‘comfortingstressful’ with a mean of 60.813 (again this mirrored the Batwa data). For any word-pairing a mean of > 60 denotes that on average respondents’ associated negative rather than positive emotions or attitudes towards fire within that word-pairing. Only two of the eleven word-pairings had a mean of less than 60 (Table 6.32), showing that the NBA cohort had an overall negative framing of fire. The two word-pairings with a mean of less than 60 were attractingrepelling (mean = 55.096, St. Dev. = 32.648, median = 56.0) and usefulhazardous[rev] (mean = 48.037, St. Dev. = 31.533, median = 59.0) (this disparity between the median and the much lower mean value denotes that a large proportion of the population answered ‘strongly positively’ to this word-pair). Furthermore one more word-pair had a median < 60 but a mean > 60 (comfortingstressful – mean = 60.813, St. Dev. =

35.439, median = 59.0) and another one had a median of 60 (Gift threat – mean = 62.699, St. Dev. = 36.057, median = 60.0); both of which are classifiable as ‘neither positive nor negative’. Analysis of the NBA data shows that of the eleven word-pairings seven mean values can be classed as showing that the NBA cohort responded ‘negatively’ (mean = >70). This suggests that within the NBA mindset fire is viewed much more negatively than the Batwa, and more negatively than the UK cohort. The three word-pairings that had a median < 60 were all only slightly less than 60 (56-59 range), with mean values ranging from 48-61) thus suggesting that across the population surveyed an awareness exists of the positive benefits of fire but within the mindset of respondents these positives (or benefits) do not outweigh the negatives (or risks).

All of the results from the NBA cohort word-pairings were not normally distributed and therefore statistical analysis specific to non-normally distributed data were applied. Most data distributions could be described as multi-modal but on occasions bi-modal and tri-modal distributions were observed.

ProtectiveRisky(rev)

The mean response was 82.55 (Std.dev = 27.68) and the median response was 74.0 which denotes that the NBA cohort perceive fire as ‘highly risky’; data is broadly bimodal (Fig.6.50). A very prominent mode of data in the 115-120 range correlates to respondents suggesting they perceived fire as very risky and not protective at all; this mode appears responsible for the mean being 8.5 points higher than the median. A second, more broad, mode can be observed clustering around the 55-70 range representing those respondents who perceived fire as being both risky and protective in almost equal proportions.

Figure 6.50: A histogram of the frequency of responses from the NBA cohort to ProtectiveRisky(rev)

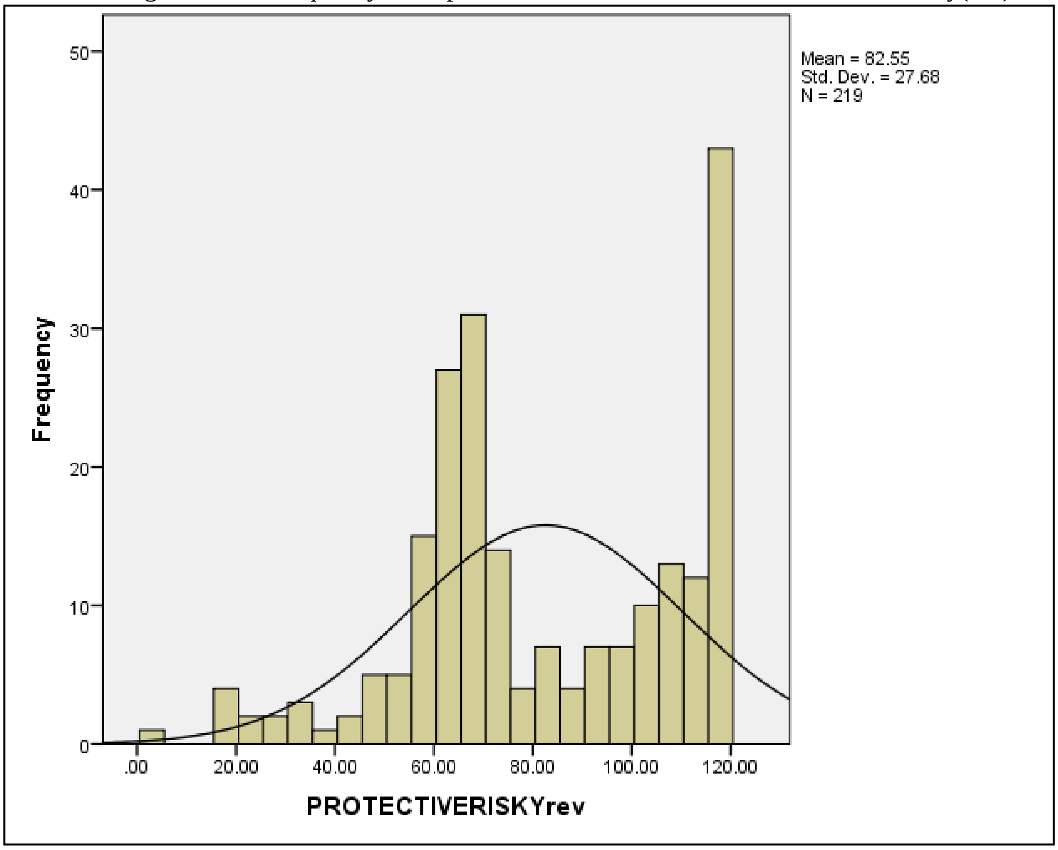
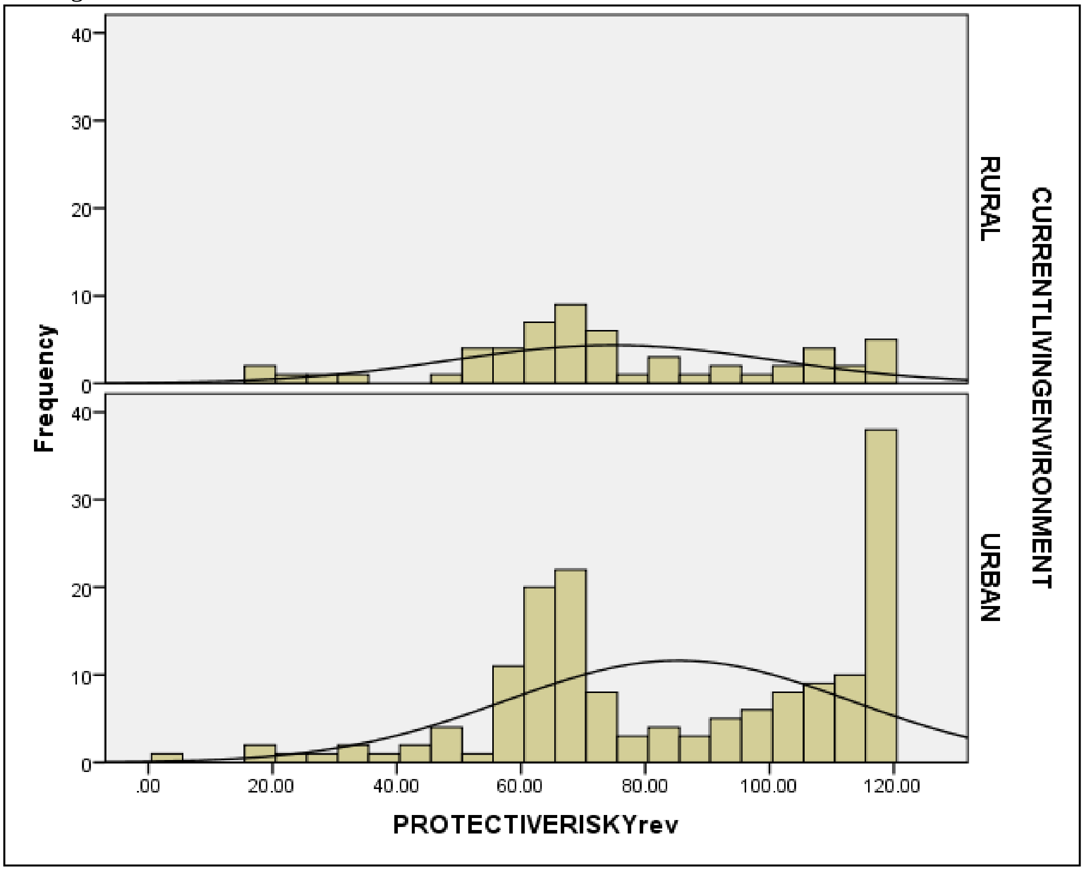


Figure 6.51: A histogram of the frequency of responses from the NBA cohort to ProtectiveRisky(rev) filtered by current living environment



	SEX	N	Mean Rank		
ProtectiveRisky (rev)	MALE	152	112.15	Chi-Square	0.573
	FEMALE	67	105.12	Df	1
	Total	219		Asymp. Sig.	0.449
	BURNTORNOT	N	Mean Rank		
ProtectiveRisky (rev)	no	49	111.48	Chi-Square	0.034
	yes	170	109.57	Df	1
	Total	219		Asymp. Sig.	0.853
	PARENTHOOD	N	Mean Rank		
ProtectiveRisky (rev)	NO	173	114.22	Chi-Square	3.661
	YES	46	94.12	Df	1
	Total	219		Asymp. Sig.	0.056
	NewAge	N	Mean Rank		
ProtectiveRisky (rev)	18-24	142	113.77		
	25-34	52	101.00	Chi-Square	7.753
	35-44	15	113.40	Df	5
	45-54	6	133.83	Asymp. Sig.	0.170
	55-64	2	77.00		
	65+	2	12.25		
	Total	219			
	Smokingstatus	N	Mean Rank		
ProtectiveRisky (rev)	never smoked	188	112.03	Chi-Square	1.899
	ex-smoker	21	103.40	Df	2
	current smoker	10	85.65	Asymp. Sig.	0.387
	Total				
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
ProtectiveRisky (rev)	RURAL	159	106.51	Chi-Square	1.760
	URBAN	60	119.24	Df	1
	Total	219		Asymp. Sig.	0.185
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
ProtectiveRisky (rev)	RURAL	108	108.71	Chi-Square	0.089
	URBAN	111	111.26	Df	1
	Total	209		Asymp. Sig.	0.766
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
ProtectiveRisky (rev)	RURAL	57	92.43	Chi-Square	5.930
	URBAN	162	116.18	Df	1
	Total	219		Asymp. Sig.	0.015
	FireUseCatNEW	N	Mean Rank		
ProtectiveRisky (rev)	Low Usage (1-3)	4	110.63	Chi-Square	1.241
	Medium Usage (4-6)	61	102.34	Df	2
	High Usage (7-10)	154	113.02	Asymp. Sig.	0.538

Table 6.33: Kruskal-Wallis test data with ProtectiveRisky(rev) as the test variable and a number of demographic grouping variables

Kruskal-Wallis testing identified that the variable ‘current living environment’ (χ^2 = 5.930, p = 0.015) (Table. 6.33) was the only statistically significant factor impacting the data; ‘parenthood’ was almost statistically significant (χ^2 = 3.661, p = 0.056). As can be clearly seen (Fig. 6.51) it is the urban population which perceives fire as much more risky and much less protective than the rural population (Table. 6.33). The urban population is very much responsible for the very prominent mode of data in the 115-120 range identified previously. The same relationship was not observed in the data from the UK cohort.

ExcitingDangerous

Data is multi-modally distributed (Fig.6.52). The mean response was 85.35 (Std.dev = 32.094) and the median response was 93.0 (the greatest median response calculated in this study) denoting that the NBA cohort perceive fire as 'highly dangerous'. This conclusion is reflected in Fig. 6.52 with a very prominent mode of data in the 110-120 range correlating to respondents suggesting they perceived fire as very dangerous and not exciting at all; this mode appears responsible for the median being 7.5 points higher than the mean. A much smaller mode can be observed clustering around the 50-65 range representing those respondents who perceived fire as being both exciting and dangerous in almost equal proportions. Many more respondents answered in the 65-110 range (fire is more dangerous than exciting, but has both qualities to some extent) than in the 20-50 range (fire is more exciting than dangerous, but has both qualities to some extent) (Fig.6.52).

Kruskal-Wallis testing identified no statistically significant relationships (Table. 6.34). However both 'under 10 living environment' (χ^2 = 3.688, p = 0.055) and 'current living environment' (χ^2 = 3.628, p = 0.057) were very nearly significant at the 95% confidence level (Table. 6.34); the data from these variables is plotted in a histogram (Fig. 6.53). Once again it can be seen that it is people who currently live in an urban environment who perceive fire in a more 'negative' manner, viewing fire as more dangerous and less exciting as a cohort than those who currently reside in a rural environment.

Figure 6.52: A histogram of the frequency of responses from the NBA cohort to ExcitingDangerous

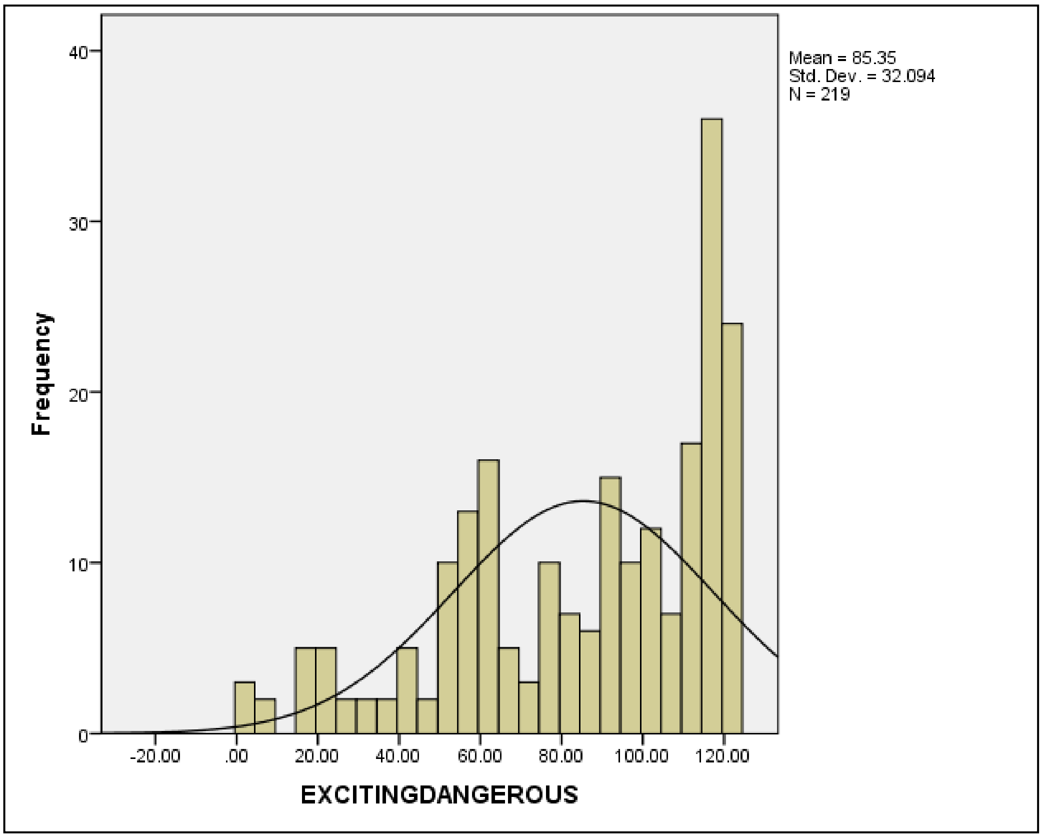
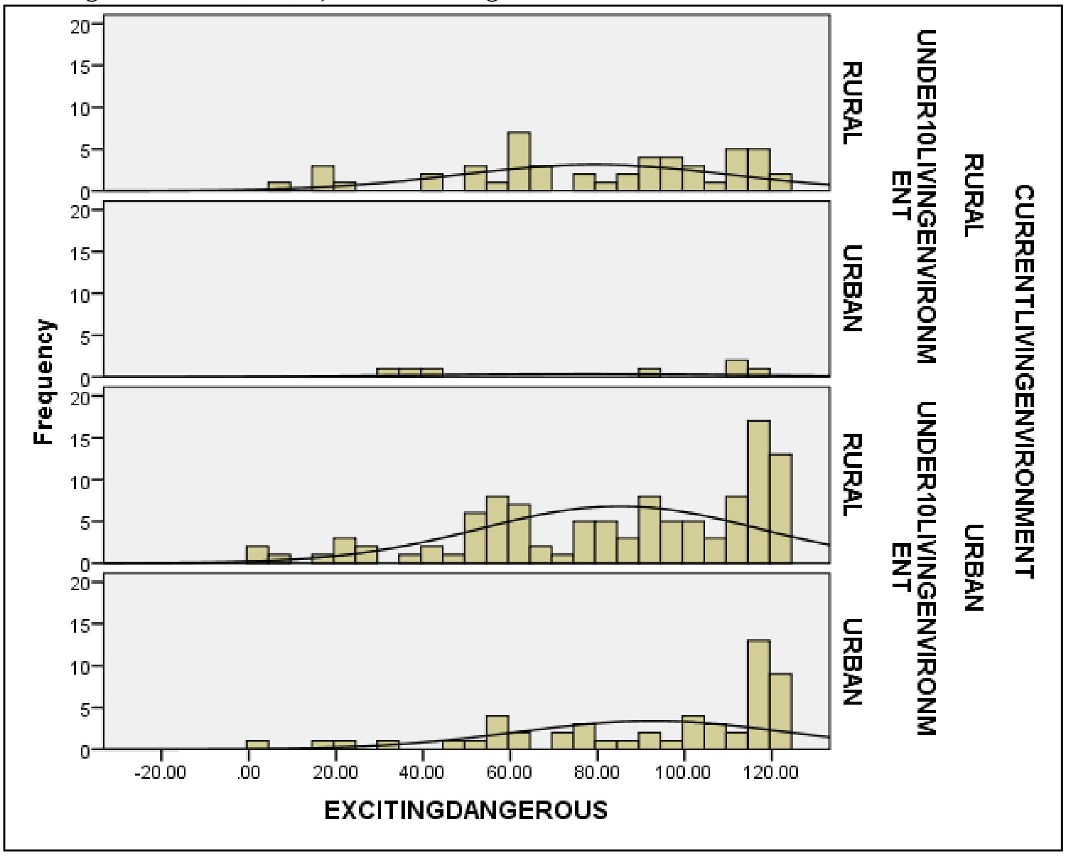


Figure 6.53: A histogram of the frequency of responses from the NBA cohort to ExcitingDangerous filtered by: i) current living environment; and, ii) under 10 living environment



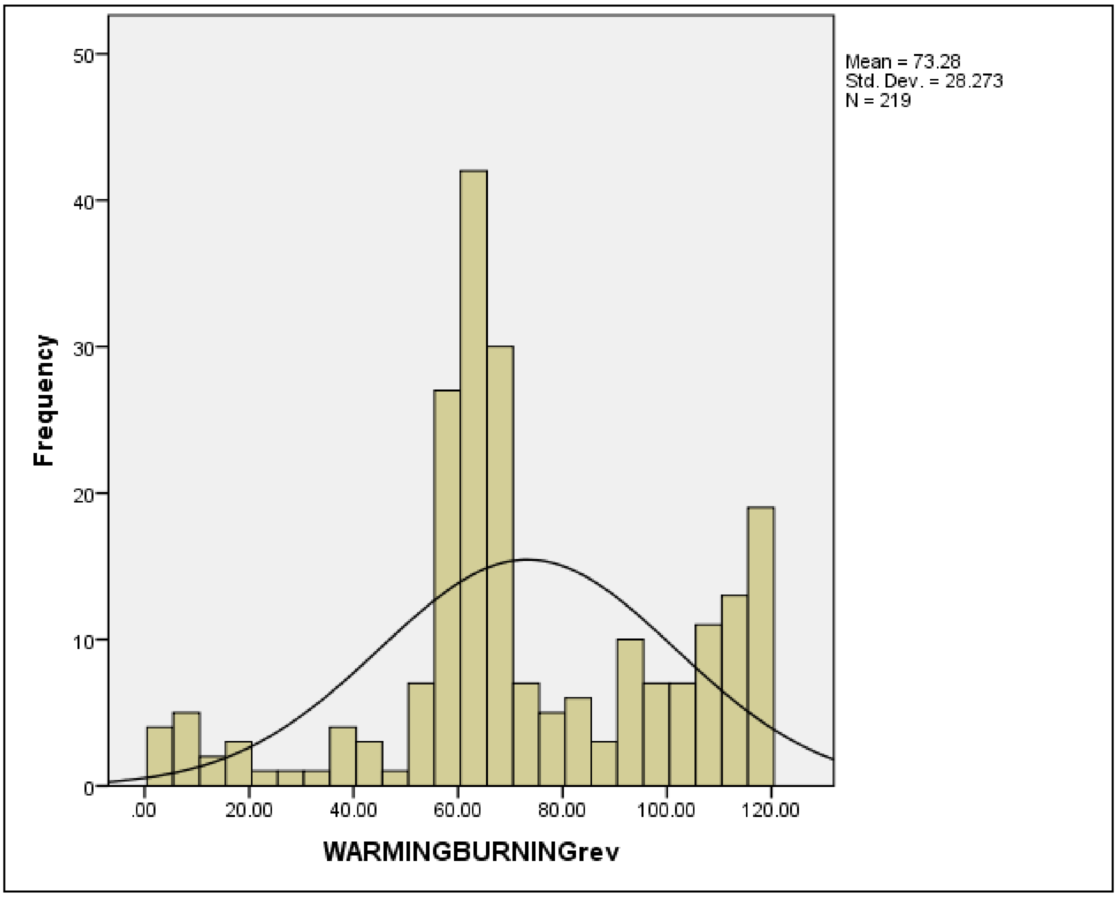
	SEX	N	Mean Rank		
ExcitingDangerous	MALE	152	106.70	Chi-Square	1.352
	FEMALE	67	117.49	Df	1
	Total	219		Asymp. Sig.	0.245
	BURNTORNOT	N	Mean Rank		
ExcitingDangerous	no	49	121.46	Chi-Square	2.068
	yes	170	106.70	Df	1
	Total	219		Asymp. Sig.	0.150
	PARENTHOOD	N	Mean Rank		
ExcitingDangerous	NO	173	113.67	Chi-Square	2.764
	YES	46	96.21	Df	1
	Total	219		Asymp. Sig.	0.096
	NewAge	N	Mean Rank		
ExcitingDangerous	18-24	142	112.10		
	25-34	52	112.12	Chi-Square	5.591
	35-44	15	111.70	Df	5
	45-54	6	78.83	Asymp. Sig.	0.348
	55-64	2	36.75		
	65+	2	60.25		
	Total	219			
	Smokingstatus	N	Mean Rank		
ExcitingDangerous	never smoked	188	111.81	Chi-Square	1.553
	ex-smoker	21	104.40	df	2
	current smoker	10		Asymp. Sig.	0.460
	Total				
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
ExcitingDangerous	RURAL	159	104.95	Chi-Square	3.688
	URBAN	60	123.38	df	1
	Total	219		Asymp. Sig.	0.055
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
ExcitingDangerous	RURAL	108	114.56	Chi-Square	1.106
	URBAN	111	105.56	df	1
	Total	209		Asymp. Sig.	0.293
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
ExcitingDangerous	RURAL	57	96.26	Chi-Square	3.628
	URBAN	162	114.83	df	1
	Total	219		Asymp. Sig.	0.057
	FireUseCatNEW	N	Mean Rank		
ExcitingDangerous	Low Usage (1-3)	4	89.13	Chi-Square	1.070
	Medium Usage (4-6)	61	115.82	df	2
	High Usage (7-10)	154	108.24	Asymp. Sig.	0.586

Table 6.34: Kruskal-Wallis test data with ExcitingDangerous as the test variable and a number of demographic grouping variables

WarmingBurning(rev)

Data is multi-modally distributed (Fig.6.54); many more people in the NBA cohort responded that fire was more burning than warming. The mean response was 73.283 (Std.dev = 28.273) and the median response was 66.0 which denotes that the NBA cohort perceive fire as 'more burning than warming'. However, as Fig. 6.54 clearly shows the most prominent mode is in the 50-70 range which denotes those respondents who view fire as having both burning and warming qualities in roughly equal measure. There are small modes at both ends of the scale, but the most prominent end-spectrum mode contains data from those people who strongly perceive fire as burning and not warming (100-120); the fact that this mode is much more prominent than the mode containing those who strongly perceive fire as warming and not burning (0-20) results in the disparity observable between the mean and median values. Kruskal-Wallis testing identified no statistically significant relationships (Table. 6.35); statistical analysis identified nothing with confidence at even the 90% confidence level. Current smokers had clearly different views than never smokers (Table. 6.35), but the small population of current smokers within the NBA cohort suggest that insufficient statistical power exists to generate sufficient significance in the results (only 4.6% of the NBA cohort classified themselves as current smokers – Table.6.31).

Figure 6.54: A histogram of the frequency of responses from the NBA cohort to WarmingBurning (rev)



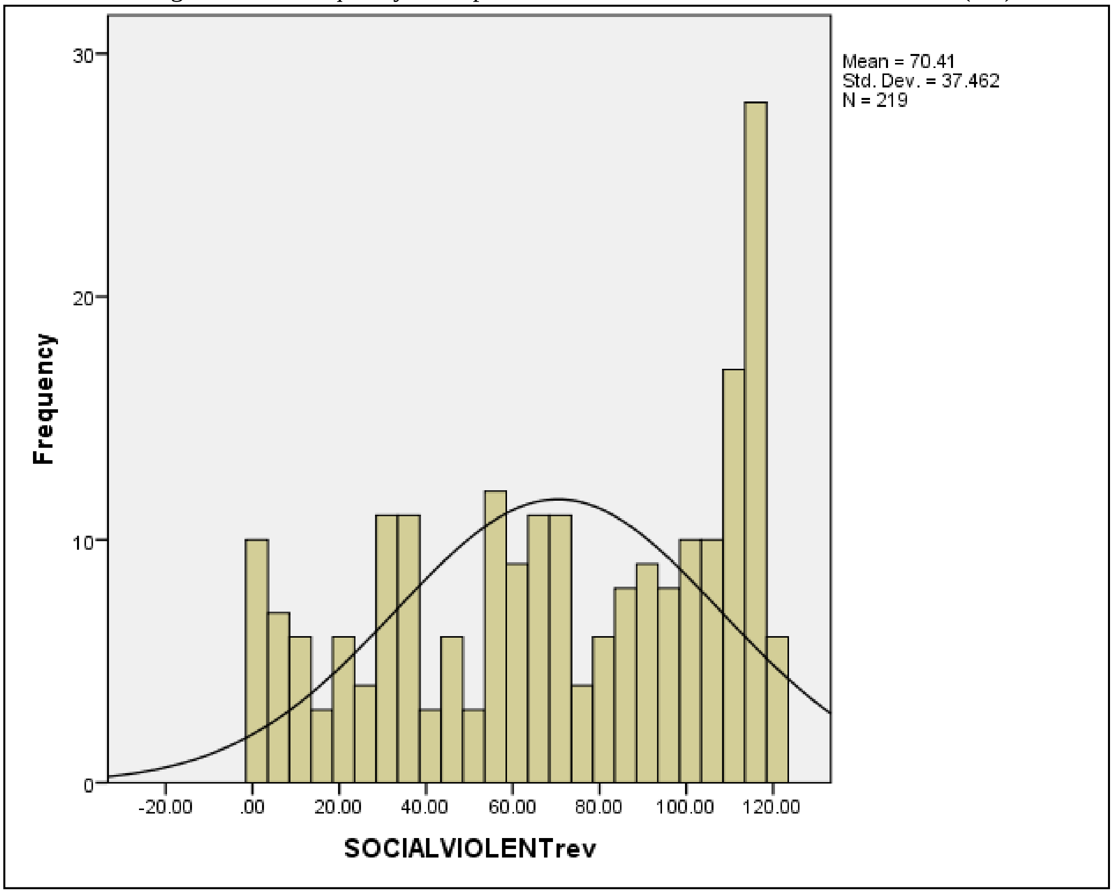
	SEX	N	Mean Rank		
WarmingBurning (rev)	MALE	152	109.03	Chi-Square	0.116
	FEMALE	67	112.19	Df	1
	Total	219		Asymp. Sig.	0.734
	BURNTORNOT	N	Mean Rank		
WarmingBurning (rev)	no	49	119.77	Chi-Square	1.501
	yes	170	107.19	Df	1
	Total	219		Asymp. Sig.	0.221
	PARENTHOOD	N	Mean Rank		
WarmingBurning (rev)	NO	173	111.52	Chi-Square	0.473
	YES	46	104.29	Df	1
	Total	219		Asymp. Sig.	0.492
	NewAge	N	Mean Rank		
WarmingBurning (rev)	18-24	142	111.56		
	25-34	52	102.46	Chi-Square	1.480
	35-44	15	108.17	Df	5
	45-54	6	105.50	Asymp. Sig.	0.915
	55-64	2	107.25		
	65+	2			
	Total	219			
	Smokingstatus	N	Mean Rank		
WarmingBurning (rev)	never smoked	188	113.38	Chi-Square	4.579
	ex-smoker	21	96.55	Df	2
	current smoker	10	74.75	Asymp. Sig.	0.101
	Total				
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
WarmingBurning (rev)	RURAL	159	111.98	Chi-Square	0.566
	URBAN	60	104.76	df	1
	Total	219		Asymp. Sig.	0.452
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
WarmingBurning (rev)	RURAL	108	115.63	Chi-Square	1.686
	URBAN	111	104.52	df	1
	Total	209		Asymp. Sig.	0.194
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
WarmingBurning (rev)	RURAL	57	108.00	Chi-Square	0.077
	URBAN	162	110.70	df	1
	Total	219		Asymp. Sig.	0.782
	FireUseCatNEW	N	Mean Rank		
WarmingBurning (rev)	Low Usage (1-3)	4	134.88	Chi-Square	1.554
	Medium Usage (4-6)	61	116.14	df	2
	High Usage (7-10)	154	106.92	Asymp. Sig.	0.460

Table 6.35: Kruskal-Wallis test data with WarmingBurning (rev) as the test variable and a number of demographic grouping variables

SocialViolent (rev)

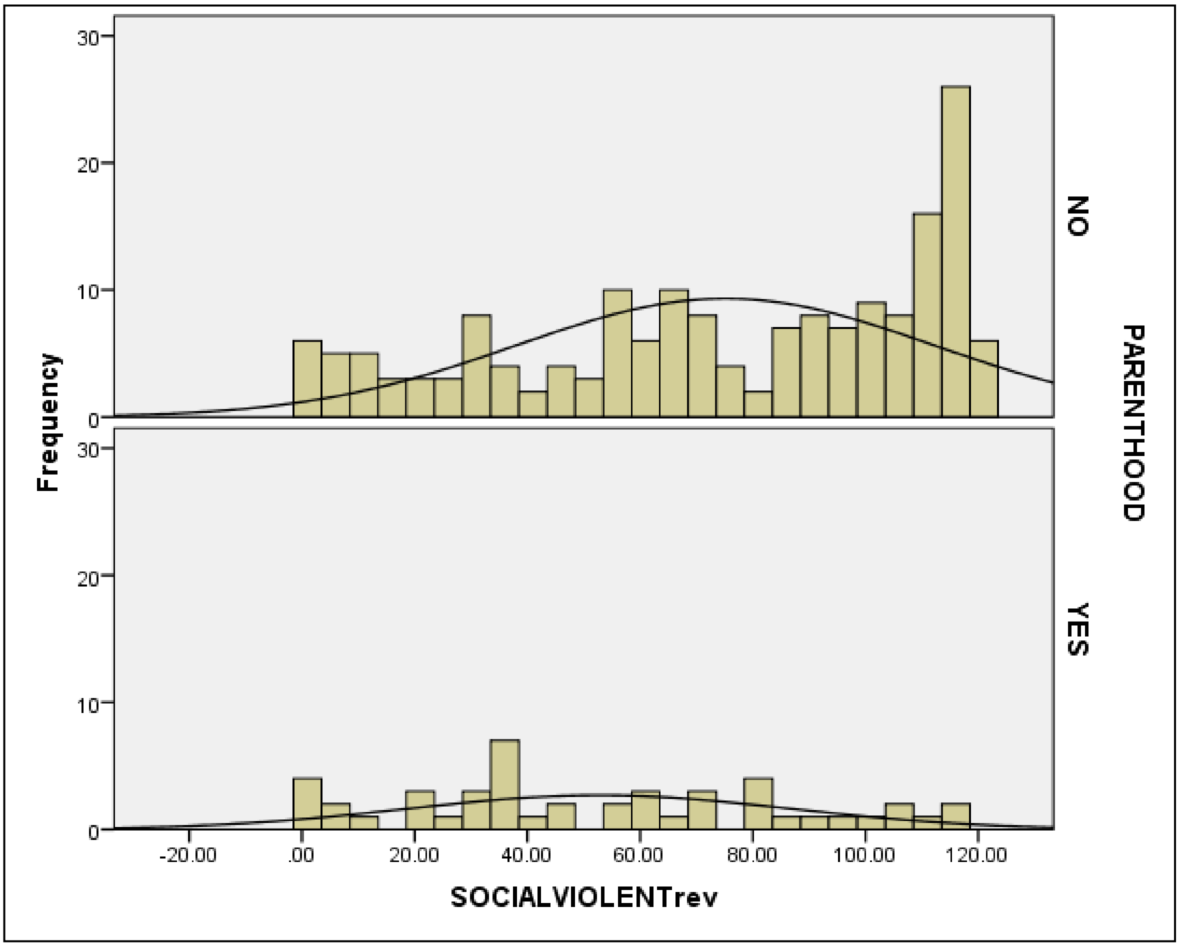
More people in the NBA cohort responded that fire was more violent than social; this is reflected in the mean and median values. The mean response was 70.406 (Std.dev = 37.462 [the highest standard deviation derived from the word-pair data in this study]) and the median response was 71.0 denoting that the NBA cohort perceive fire as ‘both violent and social *but* more violent than social'. Data is multi-modally distributed (Fig.6.55). A number of distinct modes are visible along the spectrum showing populations who frame fire as: i) only social and not violent (0-20); ii) both violent and social *but* more social than violent (30-40); iii) both violent and social in roughly equal measures (50-70); and the largest and most prominent mode iv) only violent and not social (100-120) (Fig. 6.55).

Figure 6.55: A histogram of the frequency of responses from the NBA cohort to SocialVioent (rev)



Kruskal-Wallis testing identified one very strong statistically significant relationship (Table. 6.36) with whether a respondent was a parent or not being very significant in the way that participants rated the SocialViolent word-pair (χ^2 = 13.544, p = >0.000). Those who had children were much more likely to view fire as social than those who had not yet produced, albeit the full spectrum of answers were still covered by both populations (Fig. 6.56); no other demographic variable was even close to being significant (Table 6.36).

Figure 6.56: A histogram of the frequency of responses from the NBA cohort to SocialVioent (rev)



	SEX	N	Mean Rank		
SocialViolent (rev)	MALE	152	111.34	Chi-Square	0.223
	FEMALE	67	106.96	df	1
	Total	219		Asymp. Sig.	0.637
	BURNTORNOT	N	Mean Rank		
SocialViolent (rev)	no	49	111.07	Chi-Square	0.018
	yes	170	109.69	df	1
	Total	219		Asymp. Sig.	0.893
	PARENTHOOD	N	Mean Rank		
SocialViolent (rev)	NO	173	118.12	Chi-Square	13.544
	YES	46	79.45	df	1
	Total	219		Asymp. Sig.	>0.000
	NewAge	N	Mean Rank		
SocialViolent (rev)	18-24	142	115.95		
	25-34	52	100.12	Chi-Square	5.713
	35-44	15	109.03	Df	5
	45-54	6	80.33	Asymp. Sig.	0.335
	55-64	2	101.50		
	65+	2	49.25		
	Total	219			
	Smokingstatus	N	Mean Rank		
SocialViolent (rev)	never smoked	188	111.61	Chi-Square	1.553
	ex-smoker	21	93.69	df	2
	current smoker	10	114.05	Asymp. Sig.	0.460
	Total				

	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
SocialViolent (rev)	RURAL	159	112.22	Chi-Square	0.713
	URBAN	60	104.12	Df	1
	Total	219		Asymp. Sig.	0.399
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
SocialViolent (rev)	RURAL	108	106.55	Chi-Square	0.632
	URBAN	111	113.36	Df	1
	Total	209		Asymp. Sig.	0.427
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
SocialViolent (rev)	RURAL	57	105.06	Chi-Square	0.468
	URBAN	162	111.74	Df	1
	Total	219		Asymp. Sig.	0.494
	FireUseCatNEW	N	Mean Rank		
SocialViolent (rev)	Low Usage (1-3)	4	99.00	Chi-Square	1.845
	Medium Usage (4-6)	61	119.21	Df	2
	High Usage (7-10)	154	106.64	Asymp. Sig.	0.398

Table 6.36: Kruskal-Wallis test data with SocialViolent (rev) as the test variable and a number of demographic grouping variables

SafeScary

More people in the NBA cohort responded that fire was ‘more scary than safe’. The mean response was 75.959 (Std.dev = 36.418) and the median response was 84.0 denoting that the NBA cohort perceive fire as ‘much more scary than safe’. Data is multi-modally distributed; very distinct modes are visible (Fig.6.57). One small mode shows a proportion of the population who think of fire as only safe and not scary (0-20). A second, and much more prominent mode (100-120), perceive ‘fire as scary and not safe’; the presence of this very large distinctive mode accounts for the very high mean and median values.

Kruskal-Wallis testing identified three statistically significant relationships between responses to this word-pair and demographic variables (Table. 6.37); the breadth of a respondents’ fire-use experience ($\chi^2 = 9.258$, p = 0.010) (Fig. 6.58), adolescent living environment ($\chi^2 = 4.502$, p = 0.034) (Fig. 6.59) and current living environment ($\chi^2 = 7.673$, p = 0.006) (Fig. 6.60).

Figure 6.57: A histogram of the frequency of responses from the NBA cohort to SafeScary

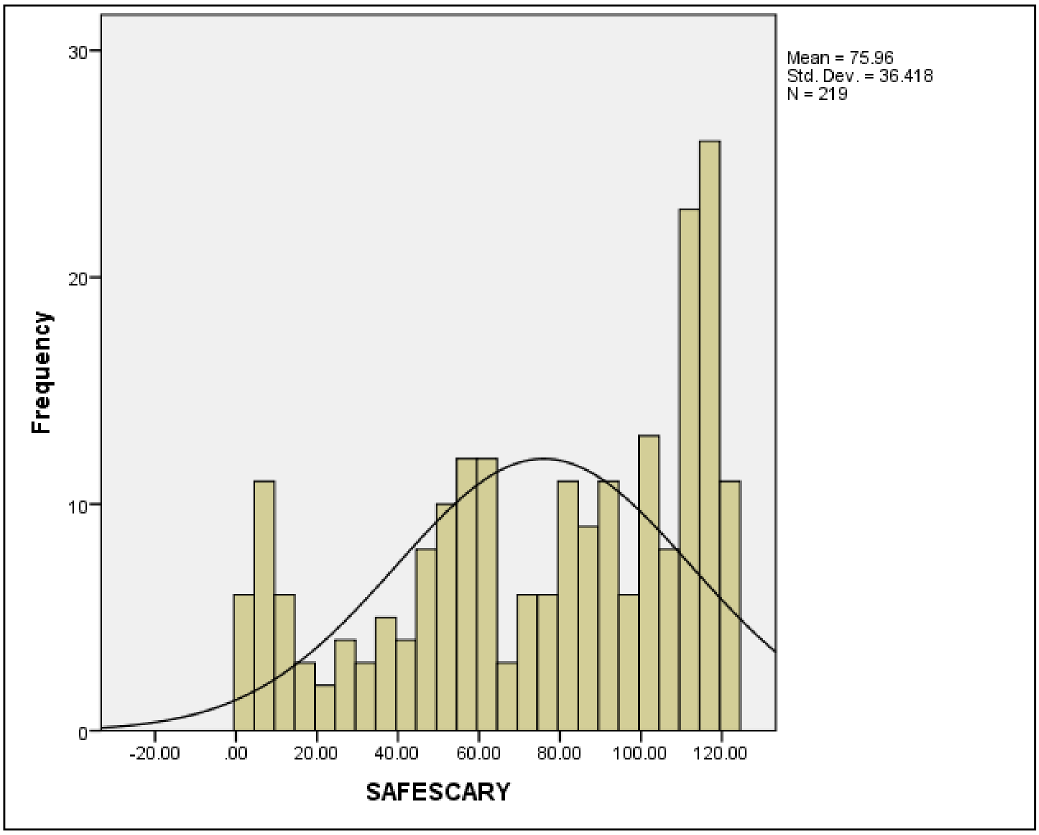


Figure 6.58: A histogram of the frequency of responses from the NBA cohort to SafeScary filtered by the breadth of a respondents' fire-use experience

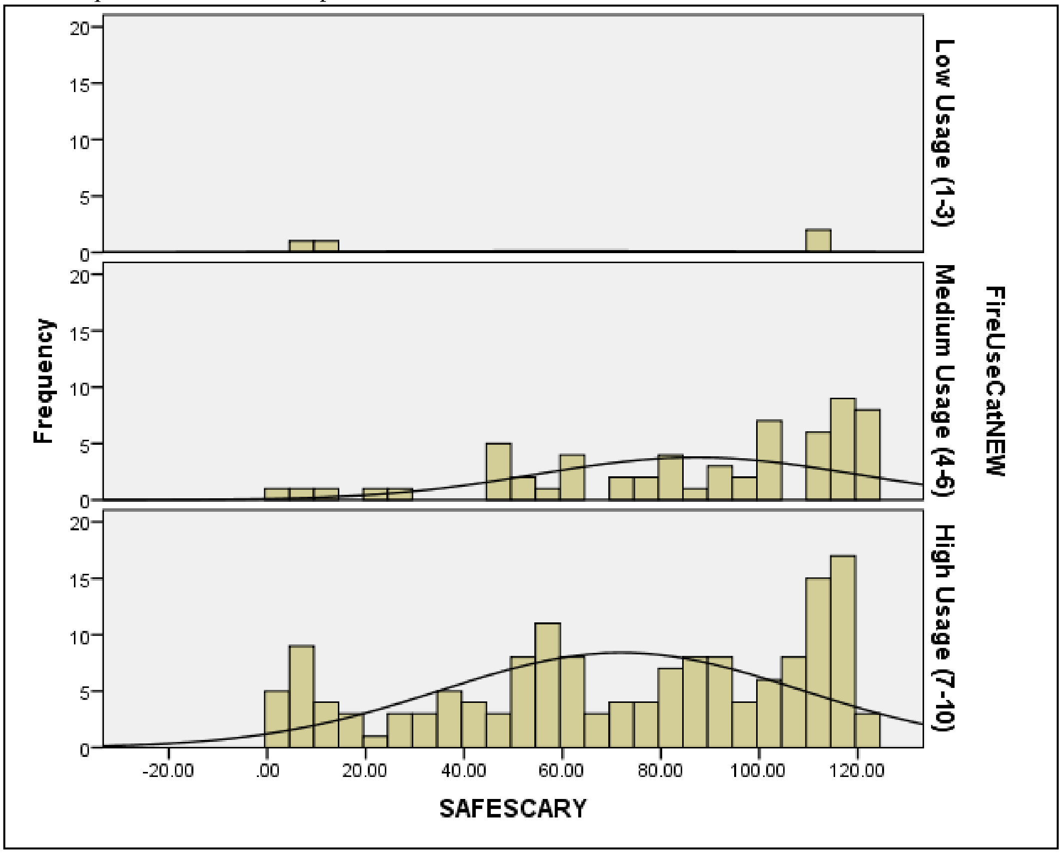


Figure 6.59: A histogram of the frequency of responses from the NBA cohort to SafeScary filtered by the respondents' Adolescent living environment

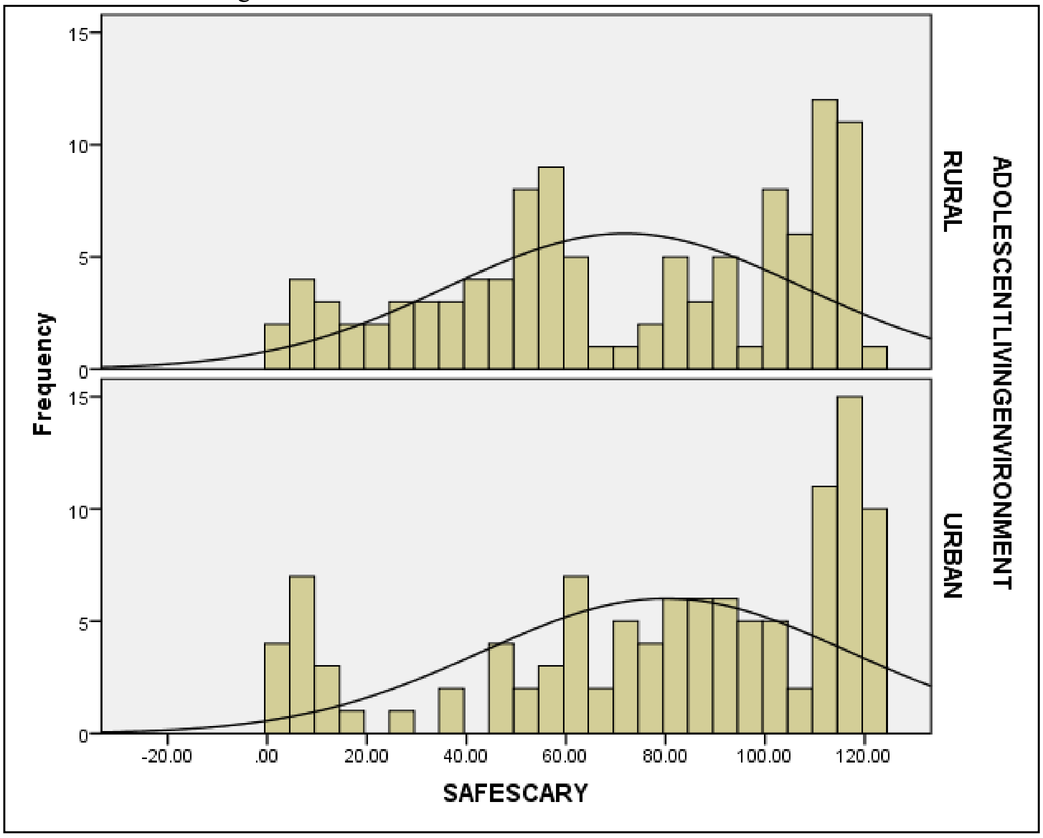
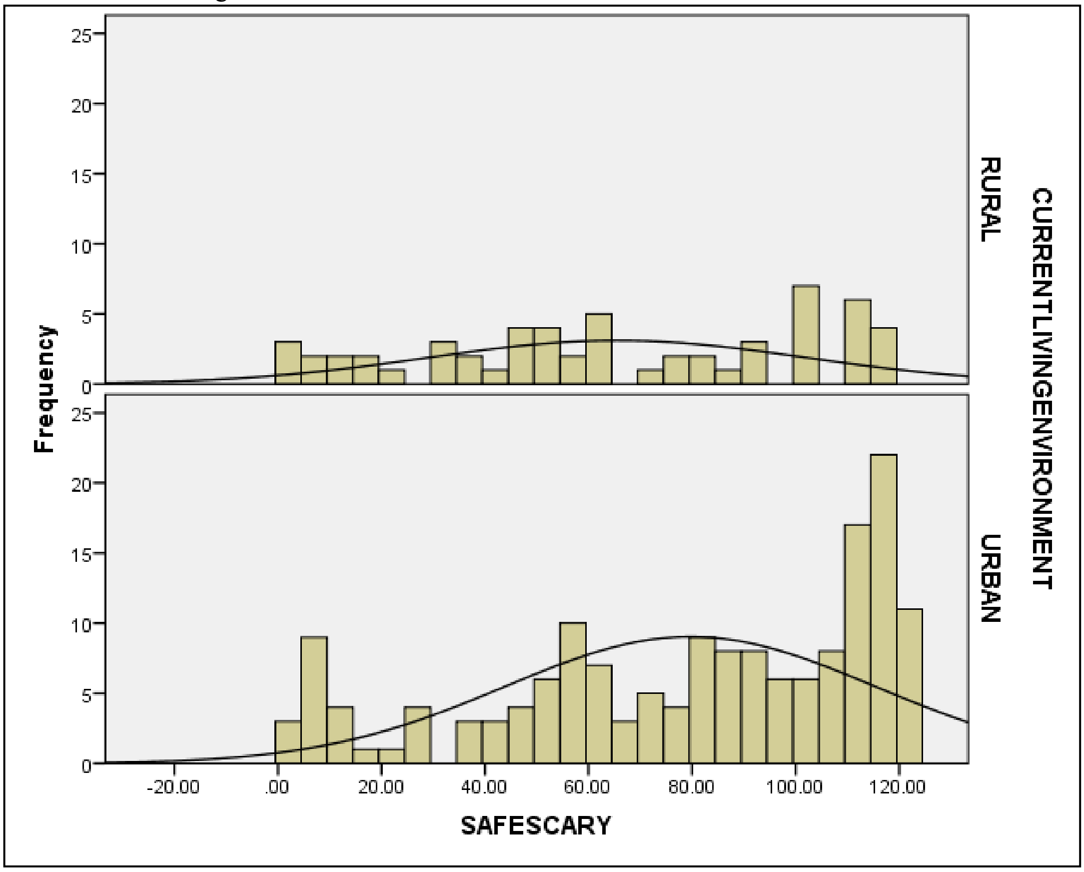


Figure 6.60: A histogram of the frequency of responses from the NBA cohort to SafeScary filtered by the respondents' current living environment



	SEX	N	Mean Rank		
SafeScary	MALE	152	108.36	Chi-Square	0.334
	FEMALE	67	113.72	df	1
	Total	219		Asymp. Sig.	0.564
	BURNTORNOT	N	Mean Rank		
SafeScary	no	49	115.48	Chi-Square	0.472
	yes	170	108.42	df	1
	Total	219		Asymp. Sig.	0.492
	PARENTHOOD	N	Mean Rank		
SafeScary	NO	173	112.32	Chi-Square	1.105
	YES	46	101.27	df	1
	Total	219		Asymp. Sig.	0.293
	NewAge	N	Mean Rank		
SafeScary	18-24	142	112.02		
	25-34	52	109.74	Chi-Square	4.453
	35-44	15	103.03	df	5
	45-54	6	117.75	Asymp. Sig.	0.486
	55-64	2	90.00		
	65+	2	22.25		
	Total	219			
	Smokingstatus	N	Mean Rank		
SafeScary	never smoked	188	111.85	Chi-Square	1.287
	ex-smoker	21	95.69	df	2
	current smoker	10	105.30	Asymp. Sig.	0.526
	Total				
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
SafeScary	RURAL	159	106.13	Chi-Square	2.170
	URBAN	60	120.27	df	1
	Total	219		Asymp. Sig.	0.141
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
SafeScary	RURAL	108	100.79	Chi-Square	4.502
	URBAN	111	118.96	df	1
	Total	209		Asymp. Sig.	0.034
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
SafeScary	RURAL	57	90.01	Chi-Square	7.673
	URBAN	162	117.03	df	1
	Total	219		Asymp. Sig.	0.006
	FireUseCatNEW	N	Mean Rank		
SafeScary	Low Usage (1-3)	4	90.88	Chi-Square	9.258
	Medium Usage (4-6)	61	130.82	df	2
	High Usage (7-10)	154	102.25	Asymp. Sig.	0.010

Table 6.37: Kruskal-Wallis test data with SafeScary as the test variable and a number of demographic grouping variables

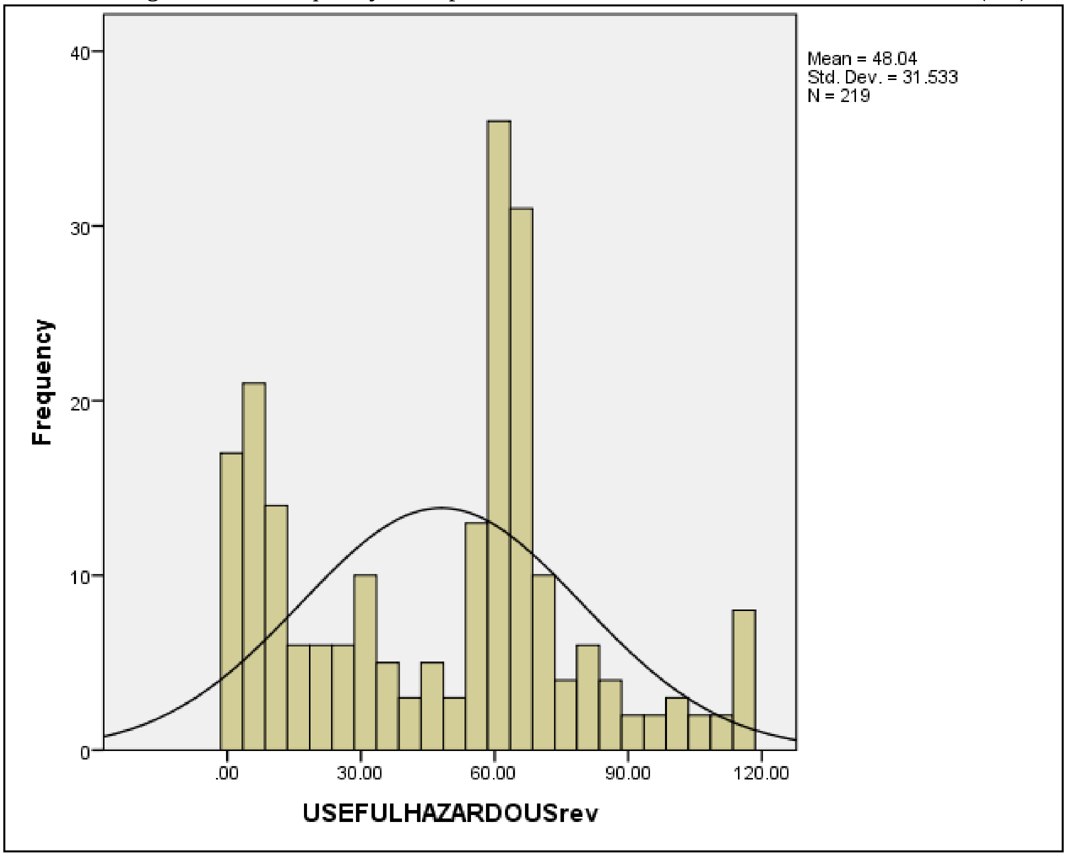
When analysing results through the lens of ‘the breadth of a respondents’ fire-use experience’ it is apparent that the 1.8% of respondents from the NBA cohort who classed as having ‘low fire-use experience’ (1-3/10 different uses) found fire to be more safe and less scary than the ‘medium’ and ‘high’ groups (Table 6.37). However in this group N = 4 only which does not enable researchers to make wider predictions based on these results. Contrary to the finding from the ‘low fire-use experience’ group the ‘medium fire-use experience’ group (4-6/10 different uses) perceived fire as significantly scarier and less safe than the ‘high group’ (Fig. 6.55), suggesting the idea that ‘*the broader a person’s personal experience with fire is then the more safely fire is framed within that person’s mind-set’* might have some credence.

When analysing results through the lens of ‘adolescent living environment’ it should be noted that the ratio of urban/rural is ~50/50 (Table 6.37). Rural residents found fire to be ‘more safe and less scary’ than urban residents; a trend that is not immediately visually noticeable (Fig. 6.59). Close scrutiny of Fig 6.59 shows that the mode on the extreme scary end of the spectrum is more pronounced which, coupled with the dearth of respondents from the urban cohort in the 20-45 range, appears sufficient to produce the statistically significant relationship identified. Trends are more easily identified when analysing the results through the lens of ‘current living environment’ (Fig. 6.60) rather than ‘adolescent living environment’ (both calculated as statistically significant). The urban population has a much more pronounced mode in the 100-120 range than the rural cohort denoting a large population who perceive fire as ‘scary and not safe at all’, which is perhaps largely responsible for the mean rankings displayed in Table. 6.37.

The findings that: i) people from rural environments; and, ii) people with a broad experience of fire-use both perceive fire as safer and less scary than their urban and/or ‘narrowly fire experienced’ contemporaries is in line with expectations. However researchers were surprised by how strongly, on average, the NBA cohort found in favour of fire being more scary than safe; while exhibiting the same preference for scary as the UK cohort did, this relationship was much more pronounced within results from the NBA cohort (see Table. 6.3 for UK data).

UsefulHazardous (rev)

Figure 6.61: A histogram of the frequency of responses from the NBA cohort to UsefulHazardous(rev)



More people in the NBA cohort responded that fire was useful rather than hazardous; the mean was 48.037 (Std.dev = 31.533) and the median of 59.0. While the NBA cohort generally perceived fire as ‘more useful than hazardous’ those participants who responded that fire was ‘more useful than hazardous’ had a greater strength of feeling on the subject than those respondents who perceived fire as more ‘hazardous than useful’. Data is tri-modally distributed (Fig.6.61). Three distinct modes outside of what would be expected from a normal distribution exist; one central and one at either end of the spectrum. The mode of people who think of fire as ‘useful and not hazardous’ [0-20] is much larger than those who think of fire as ‘hazardous and not useful’. The largest most pronounced mode (60-70) is populated by respondents who think fire is ‘equally useful and hazardous’ or ‘both useful and hazardous but very slightly more hazardous than useful’.

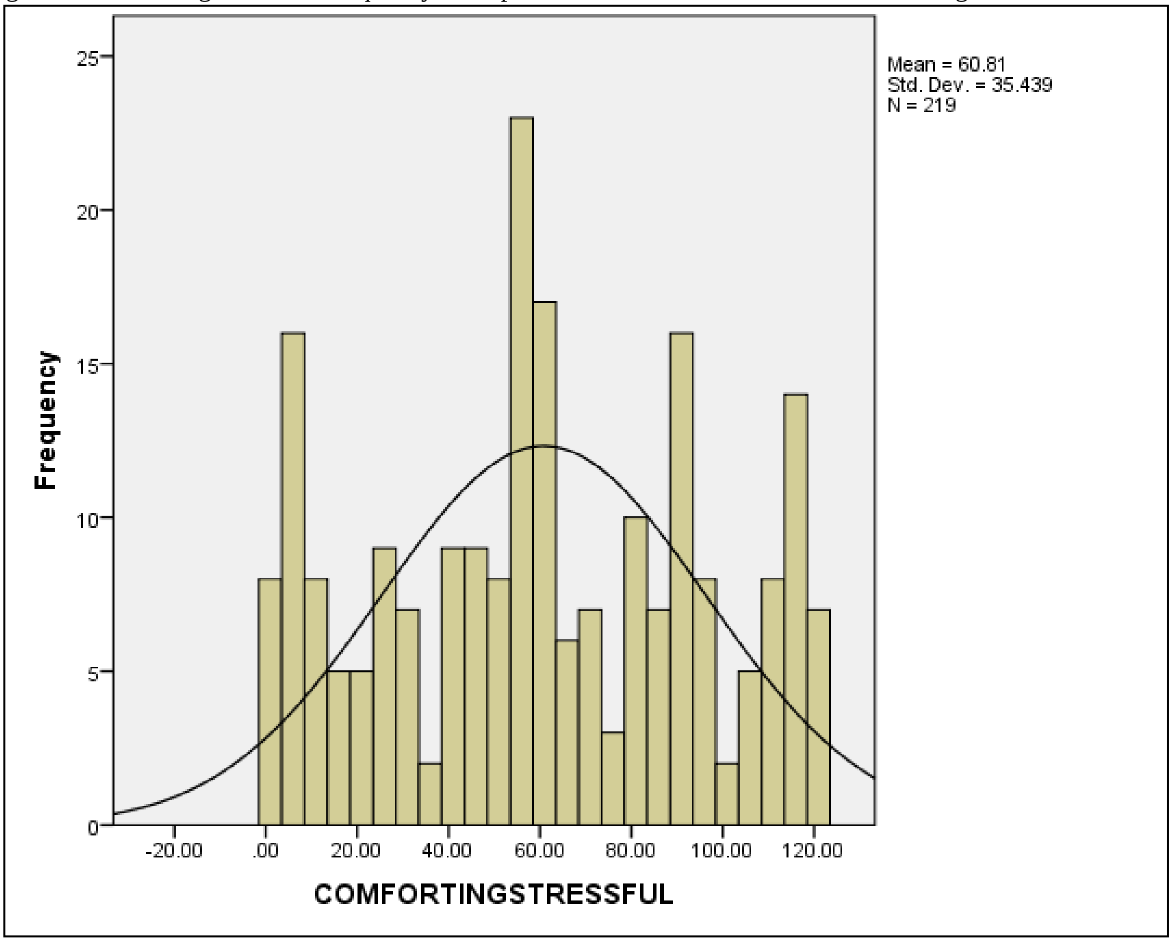
	SEX	N	Mean Rank		
UsefulHazardous (rev)	MALE	152	112.76	Chi-Square	0.945
	FEMALE	67	103.73	df	1
	Total	219		Asymp. Sig.	0.331
	BURNTORNOT	N	Mean Rank		
UsefulHazardous (rev)	no	49	122.42	Chi-Square	2.426
	yes	170	106.42	df	1
	Total	219		Asymp. Sig.	0.119
	PARENTHOOD	N	Mean Rank		
UsefulHazardous (rev)	NO	173	111.65	Chi-Square	0.561
	YES	46	103.78	df	1
	Total	219		Asymp. Sig.	0.454
	NewAge	N	Mean Rank		
UsefulHazardous (rev)	18-24	142	111.85		
	25-34	52	107.00	Chi-Square	1.550
	35-44	15	96.23	df	5
	45-54	6	115.42	Asymp. Sig.	0.907
	55-64	2	110.00		
	65+	2	143.50		
	Total	219			
	Smokingstatus	N	Mean Rank		
UsefulHazardous (rev)	never smoked	188	109.27	Chi-Square	0.249
	ex-smoker	21	116.55	df	2
	current smoker	10	110.00	Asymp. Sig.	0.883
	Total				
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
UsefulHazardous (rev)	RURAL	159	106.53	Chi-Square	1.737
	URBAN	60	119.18	df	1
	Total	219		Asymp. Sig.	0.188
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
UsefulHazardous (rev)	RURAL	108	105.56	Chi-Square	1.049
	URBAN	111	114.32	df	1
	Total	209		Asymp. Sig.	0.306
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
UsefulHazardous (rev)	RURAL	57	102.54	Chi-Square	1.070
	URBAN	162	112.63	df	1
	Total	219		Asymp. Sig.	0.301
	FireUseCatNEW	N	Mean Rank		
UsefulHazardous (rev)	Low Usage (1-3)	4	120.38	Chi-Square	1.039
	Medium Usage (4-6)	61	116.43	df	2
	High Usage (7-10)	154	107.19	Asymp. Sig.	0.595

Table 6.38: Kruskal-Wallis test data with UsefulHazardous(rev) as the test variable and a number of demographic grouping variables

Kruskal-Wallis testing identified no statistically significant relationships (Table. 6.38). However when filtering for whether a respondent had been previously burnt or not there was a marked difference in Mean Rankings (no = 122.42, yes = 106.42, (χ^2 = 2.426, p = 0.119) showing that those who had been burnt thought of fire as more useful than those uninjured by fire. However the 22%/78% ratio between the two groups (Table 6.31) mean that conceivably not enough statistical power exists to detect a statistical significance; perhaps if this was a 50/50 split greater confidence could have been generated in the observed relationship.

ComfortingStressful

Figure 6.62: A histogram of the frequency of responses from the NBA cohort to ComfortingStressful



Participants from the NBA cohort of this cross-cultural study responded that fire was both comforting and stressful in equal measures. This assessment is reflected in the near identical and balanced (i.e. close to 60) mean and median values; the mean response was 60.813 (Std.dev = 35.439) and the median response was 59.0. Data is multimodal (Fig.6.62). Prominent modes exist at each end of the spectrum (Fig.6.62) (those who think fire is only comforting and not stressful and vice versa) but the most prominent mode (55-65) represents those who think that fire is both comforting and stressful in equal, or almost equal, measures).

	SEX	N	Mean Rank		
ComfortingStressful	MALE	152	108.66	Chi-Square	0.222
	FEMALE	67	113.04	Df	1
	Total	219		Asymp. Sig.	0.638
	BURNTORNOT	N	Mean Rank		
ComfortingStressful	no	49	117.44	Chi-Square	0.870
	yes	170	107.86	Df	1
	Total	219		Asymp. Sig.	0.351
	PARENTHOOD	N	Mean Rank		
ComfortingStressful	NO	173	113.00	Chi-Square	1.847
	YES	46	98.72	Df	1
	Total	219		Asymp. Sig.	0.174
	NewAge	N	Mean Rank		
ComfortingStressful	18-24	142	112.17		
	25-34	52	108.97	Chi-Square	4.311
	35-44	15	114.50	Df	5
	45-54	6	83.42	Asymp. Sig.	0.506
	55-64	2	32.50		
	65+	2	106.50		
	Total	219			
	Smokingstatus	N	Mean Rank		
ComfortingStressful	never smoked	188	113.67	Chi-Square	4.487
	ex-smoker	21	86.26	Df	2
	current smoker	10	90.90	Asymp. Sig.	0.106
	Total				
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
ComfortingStressful	RURAL	159	106.89	Chi-Square	1.401
	URBAN	60	118.25	df	1
	Total	219		Asymp. Sig.	0.236
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
ComfortingStressful	RURAL	108	111.53	Chi-Square	0.125
	URBAN	111	108.51	df	1
	Total	209		Asymp. Sig.	0.724
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
ComfortingStressful	RURAL	57	108.26	Chi-Square	0.058
	URBAN	162	110.61	df	1
	Total	219		Asymp. Sig.	0.810
	FireUseCatNEW	N	Mean Rank		
ComfortingStressful	Low Usage (1-3)	4	115.50	Chi-Square	0.065
	Medium Usage (4-6)	61	111.17	df	2
	High Usage (7-10)	154	109.39	Asymp. Sig.	0.968

Table 6.39: Kruskal-Wallis test data with ComfortingStressful as the test variable and a number of demographic grouping variables

Other modes exist in the 80-100 range (denoting those who think fire is mostly stressful, but also slightly comforting) and the 20-40 range (mirroring its 80-100 counterpart). Kruskal-Wallis testing identified no statistically significant relationships (Table. 6.39). However when filtering for smoking status there was a marked difference in Mean Rankings (never smoked = 113.67, ex-smoker = 86.26, current smoker = 90.90) (χ^2 = 4.487, p = 0.106) showing that those who had a history of smoking though of fire as more comforting than those who had never smoked (Table. 6.39). However the 85.8% of never smokers (9.6% ex-smokers and 4.6% current smokers) (Table 6.31) mean that perhaps not enough power exists to detect a statistical significance; perhaps if this was more of balanced split between the three groups then a higher degree of confidence could have been generated in the observed relationship.

FriendlyFearsome

NBA participants responded that fire was more fearsome than friendly. The robustness of this assessment is reflected in the near identical mean and median values; the mean response was 72.712 (Std.dev = 33.330) and the median response was 71.0. Data is multi-modally distributed; Fig. 6.63 clearly shows two very distinct modes outside of what would be expected from a normal distribution, and a number of other smaller accumulations of data. One mode is at the fearsome end of the spectrum (105-120) (those who think fire is only fearsome and not friendly at all). The second prominent mode (50-70) (those who think that fire is both friendly and fearsome in equal [or almost] measures); many more people answered in the fearsome side of the spectrum (61-120) than did in the friendly side (1-59). Kruskal-Wallis identified one strongly statistically significant relationship; ‘parenthood’ (X2 = 5.646, p = 0.017) (Table. 6.40). Those without children can be seen to populate the prominent mode at the fearsome end of the spectrum in the 105-120 range (Fig. 6.64); Mean Rankings back up this observation (No children = 115.25, children = 90.27) (Table. 6.40). It can be surmised that in fact rather than having children or not it is perhaps the age of respondents which is significant in the perception of fire as either friendly or fearsome (younger people were more likely to view fire as fearsome). This assumption is backed up in the Mean Ranks for ‘age’ with those in the 18-34 age groups having a Mean Rank of ~112-

Figure 6.63: A histogram of the frequency of responses from the NBA cohort to FriendlyFearsome

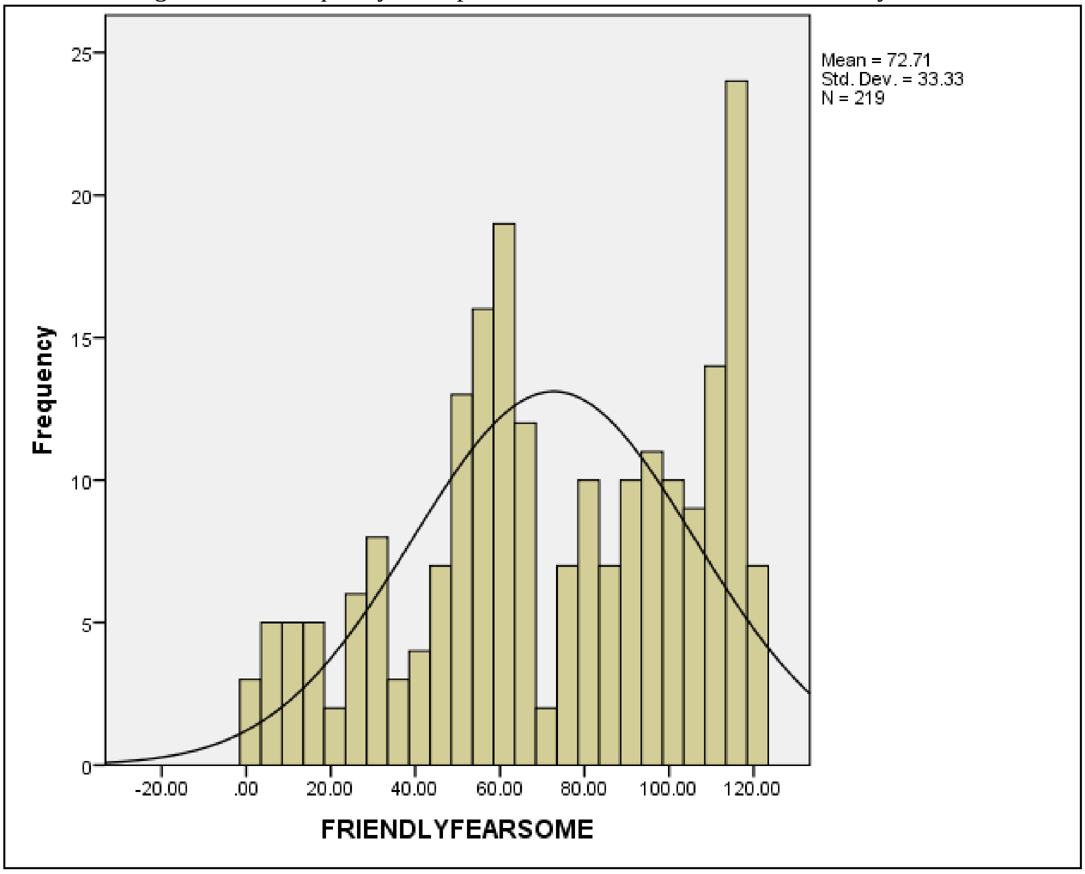
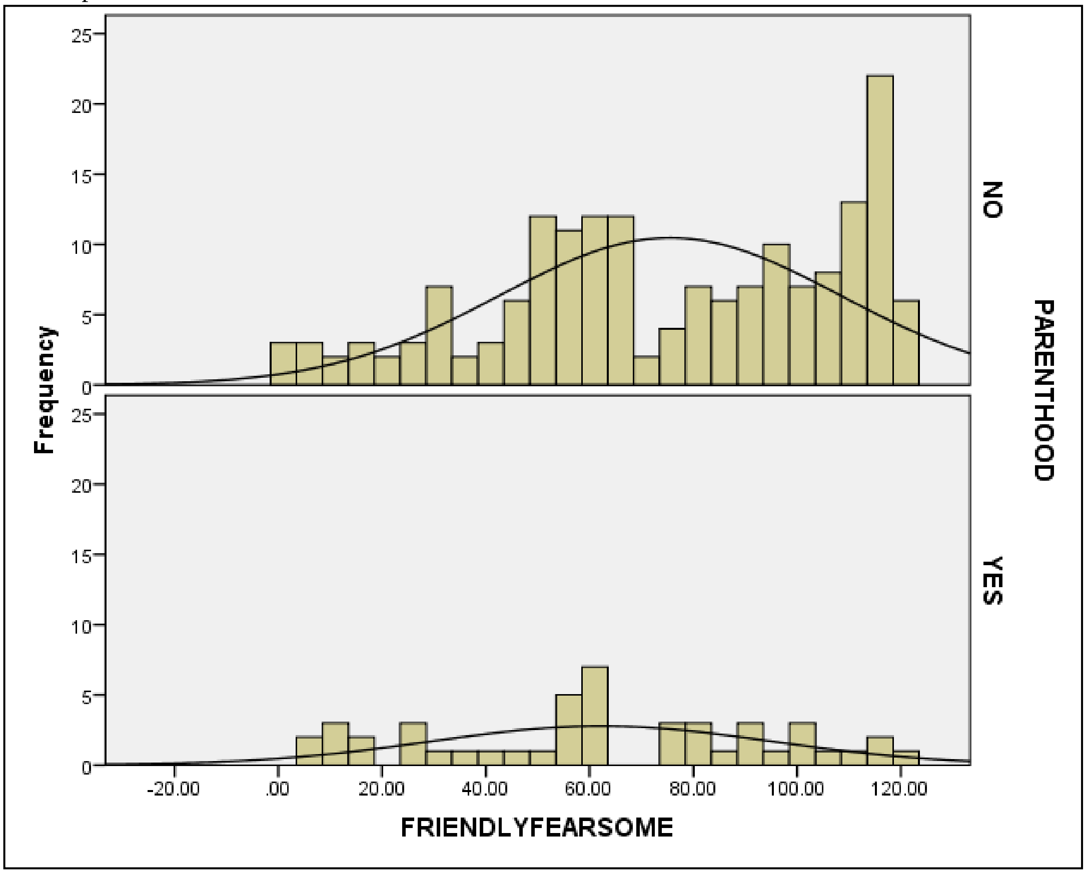


Figure 6.64: A histogram of the frequency of responses from the NBA cohort to FriendlyFearsome filtered by whether a respondent had children or not



115 while those in the 35+ age groups having Mean Ranks in the 70-90 range (Table 6.40). However again the demographic imbalance (88.5% of people are less than 35 years old) mean that perhaps not enough power exists to detect a statistical significance (χ^2 = 4.186, p = 0.523); perhaps if there was more balance between the size of the different age groups then a higher degree of confidence could have been generated in the observed relationship.

	SEX	N	Mean Rank		
FriendlyFearsome	MALE	152	109.38	Chi-Square	0.048
	FEMALE	67	111.41	Df	1
	Total	219		Asymp. Sig.	0.827
	BURNTORNOT	N	Mean Rank		
FriendlyFearsome	no	49	109.82	Chi-Square	0.001
	yes	170	110.05	Df	1
	Total	219		Asymp. Sig.	0.982
	PARENTHOOD	N	Mean Rank		
FriendlyFearsome	NO	173	115.25	Chi-Square	5.646
	YES	46	90.27	Df	1
	Total	219		Asymp. Sig.	0.017
	NewAge	N	Mean Rank		
FriendlyFearsome	18-24	142	112.44		
	25-34	52	114.80	Chi-Square	4.186
	35-44	15	88.63	df	5
	45-54	6	83.17	Asymp. Sig.	0.523
	55-64	2	90.25		
	65+	2	72.50		
	Total	219			
	Smokingstatus	N	Mean Rank		
FriendlyFearsome	never smoked	188	109.88	Chi-Square	0.174
	ex-smoker	21	107.48	df	2
	current smoker	10	117.50	Asymp. Sig.	0.917
	Total				
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
FriendlyFearsome	RURAL	159	105.55	Chi-Square	2.859
	URBAN	60	121.78	df	1
	Total	219		Asymp. Sig.	0.091
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
FriendlyFearsome	RURAL	108	104.53	Chi-Square	1.590
	URBAN	111	115.32	df	1
	Total	209		Asymp. Sig.	0.207
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
FriendlyFearsome	RURAL	57	109.59	Chi-Square	0.003
	URBAN	162	110.15	df	1
	Total	219		Asymp. Sig.	0.954
	FireUseCatNEW	N	Mean Rank		
FriendlyFearsome	Low Usage (1-3)	4	107.88	Chi-Square	0.123
	Medium Usage (4-6)	61	107.68	df	2
	High Usage (7-10)	154	110.97	Asymp. Sig.	0.941

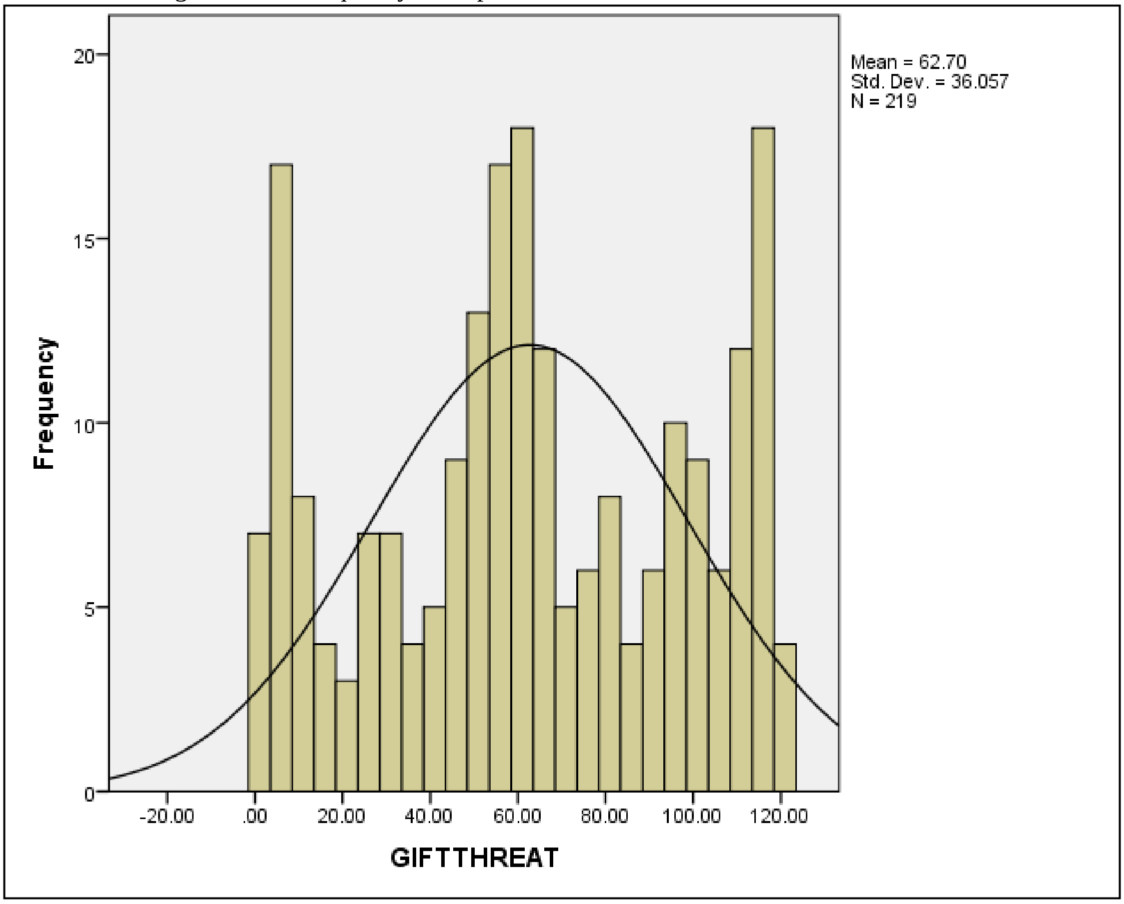
Table 6.40: Kruskal-Wallis test data with FriendlyFearsome as the test variable and a number of demographic grouping variables

GiftThreat

Participants from the NBA cohort of this cross-cultural study responded that fire was roughly a gift and a threat in equal measure. The mean response was 62.699 (Std.dev = 36.057) suggesting that the NBA saw fire as slightly more of a threat than a gift, however the median response was 60.0 suggesting that the same number of people saw fire as a gift as those who saw fire as a threat *but* those who saw fire as a threat had slightly stronger views than those who saw fire as a gift. Data is multi-modally distributed (Fig.6.65). Three very distinct modes exist distributed amongst a number of other smaller accumulations of data (Fig. 6.65). One mode at the fearsome end of the spectrum (105-120) (those who think fire is only a threat and not a gift at all) is well balanced (in both position and size) by a prominent mode at the other end of the spectrum (1-15) (those who think fire is a gift and not a threat at all). A third prominent mode (50-70) (those who think that fire is both a gift and a threat in equal [or almost] measures) is also highly visible. Deep troughs between the modes show that participants personal balances can be neatly grouped, much like the kind of data that would have been generated if a Likert scale had been used rather than the more nuanced methodology chosen; this observation shows both how effective Likert scales are for generating data on peoples' point of view, but also how much better this methodology is than a Likert scale due to the increased resolution of participants' answers.

Kruskal-Wallis testing identified no statistically significant relationships (Table. 6.41). While differences of at least 10 points are visible within the Mean Ranks of all three 'living environment demographics' (under 10, adolescent and current) (Table. 6.41), with those answering 'rural' consistently viewing fire as more of a gift than a threat, p-values only ranged from 0.103-0.247. This is despite the fact that the 'adolescent living environment' variable had pretty much a 50/50 split between urban and rural residents and therefore cannot be denigrated for insufficient generatable statistical power (in fact the ‘adolescent living environment’ variable had the largest p-value of any of the ‘living environment’ variables).

Figure 6.65: A histogram of the frequency of responses from the NBA cohort to GiftThreat



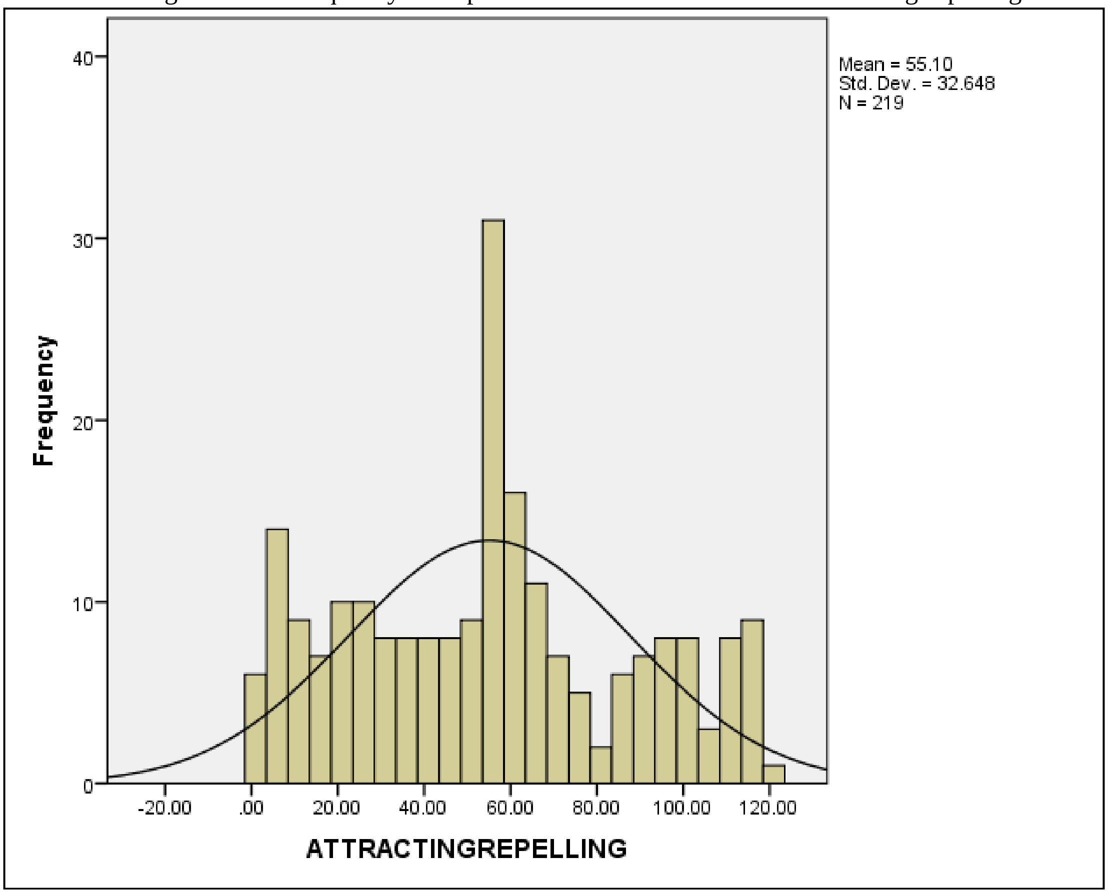
	SEX	N	Mean Rank		
GiftThreat	MALE	152	110.60	Chi-Square	0.044
	FEMALE	67	108.64	Df	1
	Total	219		Asymp. Sig.	0.833
	BURNTORNOT	N	Mean Rank		
GiftThreat	No	49	110.52	Chi-Square	0.004
	Yes	170	109.85	Df	1
	Total	219		Asymp. Sig.	0.948
	PARENTHOOD	N	Mean Rank		
GiftThreat	NO	173	111.75	Chi-Square	0.631
	YES	46	103.40	Df	1
	Total	219		Asymp. Sig.	0.427
	NewAge	N	Mean Rank		
GiftThreat	18-24	142	108.99		
	25-34	52	110.23	Chi-Square	
	35-44	15	113.40	Df	
	45-54	6	120.67	Asymp. Sig.	0.510
	55-64	2	129.75		2
	65+	2	98.50		0.992
	Total	219			

	Smokingstatus	N	Mean Rank		
GiftThreat	never smoked	188	110.54	Chi-Square	0.302
	ex-smoker	21	110.26	Df	2
	current smoker	10	99.25	Asymp. Sig.	0.860
	Total				
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
GiftThreat	RURAL	159	105.71	Chi-Square	2.664
	URBAN	60	121.38	Df	1
	Total	219		Asymp. Sig.	0.103
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
GiftThreat	RURAL	108	104.98	Chi-Square	1.339
	URBAN	111	114.98	Df	1
	Total	209		Asymp. Sig.	0.247
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
GiftThreat	RURAL	57	100.27	Chi-Square	1.817
	URBAN	162	113.42	Df	1
	Total	219		Asymp. Sig.	0.178
	FireUseCatNEW	N	Mean Rank		
GiftThreat	Low Usage (1-3)	4	127.50	Chi-Square	0.640
	Medium Usage (4-6)	61	105.74	Df	2
	High Usage (7-10)	154	111.23	Asymp. Sig.	0.726

Table 6.41: Kruskal-Wallis test data with GiftThreat as the test variable and a number of demographic grouping variables

AttractingRepelling

Figure 6.66: A histogram of the frequency of responses from the NBA cohort to AttractingRepelling



	SEX	N	Mean Rank		
AttractingRepelling	MALE	152	113.22	Chi-Square	1.286
	FEMALE	67	102.69	Df	1
	Total	219		Asymp. Sig.	0.257
	BURNTORNOT	N	Mean Rank		
AttractingRepelling	no	49	109.60	Chi-Square	0.002
	yes	170	110.11	Df	1
	Total	219		Asymp. Sig.	0.960
	PARENTHOOD	N	Mean Rank		
AttractingRepelling	NO	173	109.36	Chi-Square	0.084
	YES	46	112.41	df	1
	Total	219		Asymp. Sig.	0.771
	NewAge	N	Mean Rank		
AttractingRepelling	18-24	142	110.07		
	25-34	52	107.64	Chi-Square	1.395
	35-44	15	125.07	df	5
	45-54	6	96.33	Asymp. Sig.	0.925
	55-64	2	113.50		
	65+	2	90.50		
	Total	219			
	Smokingstatus	N	Mean Rank		
AttractingRepelling	never smoked	188	110.39	Chi-Square	1.656
	ex-smoker	21	117.60	df	2
	current smoker	10	86.75	Asymp. Sig.	0.437
	Total				
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
AttractingRepelling	RURAL	159	110.77	Chi-Square	0.085
	URBAN	60	107.97	df	1
	Total	219		Asymp. Sig.	0.770
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
AttractingRepelling	RURAL	108	103.47	Chi-Square	2.265
	URBAN	111	116.36	df	1
	Total	209		Asymp. Sig.	0.132
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
AttractingRepelling	RURAL	57	113.75	Chi-Square	0.271
	URBAN	162	108.68	df	1
	Total	219		Asymp. Sig.	0.603
	FireUseCatNEW	N	Mean Rank		
AttractingRepelling	Low Usage (1-3)	4	158.25	Chi-Square	3.793
	Medium Usage (4-6)	61	100.89	df	2
	High Usage (7-10)	154	112.35	Asymp. Sig.	0.150

Table 6.42: Kruskal-Wallis test data with AttractingRepelling as the test variable and a number of demographic grouping variables

The mean response from the NBA cohort was 55.096 (Std.dev = 32.648) and the median response was 56.0 suggesting that the NBA perceive fire as slightly more attracting than repelling. The distribution is broadly ‘trimodal’ (Fig.6.66) but the distribution appears very different from previous word-pairs. This is because one prominent mode exists in the 55-65 range (those who think that fire is both attracting and repelling in equal [or almost] measures). In the other part of the 'attracting spectrum' (0-55) results are fairly constant with a small mode of extra respondents grouping within the 0-10 range (those who think fire is only attracting and not repelling at all). Within the 'repelling spectrum' (65-120) results are also fairly constant with the exception of a few troughs within the grouping of participants who responded that fire was more attracting than repelling; these troughs, added to the fact that 'very repelling' mode (105-120) is smaller than the very attracting mode (0-10, are responsible for the mean and median values being less than 60. Kruskal-Wallis testing identified no statistically significant relationships (Table. 6.42); no demographic variables were even close to being significant. After scouring the data (Table. 6.42) the most interesting statistic appears to be the fact that when looking at the breadth of a participant's fire-use the 'medium usage' group found fire to be more attracting than the 'high-usage' group (by more than 10 ranking points); but it is reiterated here that this relationship was not deemed statistically significant at the 95% confidence level.

CleansingDestructive

Data is multi-modally distributed (Fig.6.67) but the distribution appears very different from previous word-pairs. This is due to the existence of one prominent mode (100-120) (those who think that fire is either entirely destructive or mostly destructive and only slightly cleansing) which completely dominates the histogram; a second prominent mode visible (55-65) denotes those respondents who view fire as both cleansing and destructive in equal, or almost equal, measure. Therefore it comes as no surprise to learn that results show that statistically the NBA cohort of this cross-cultural study perceive fire as far more destructive than cleansing. This is evidently a very strongly held view as the mean response from the NBA cohort was 81.146 (Std.dev = 33.357) and the median response was 90.0.

Figure 6.67: A histogram of the frequency of responses from the NBA cohort to CleansingDestructive

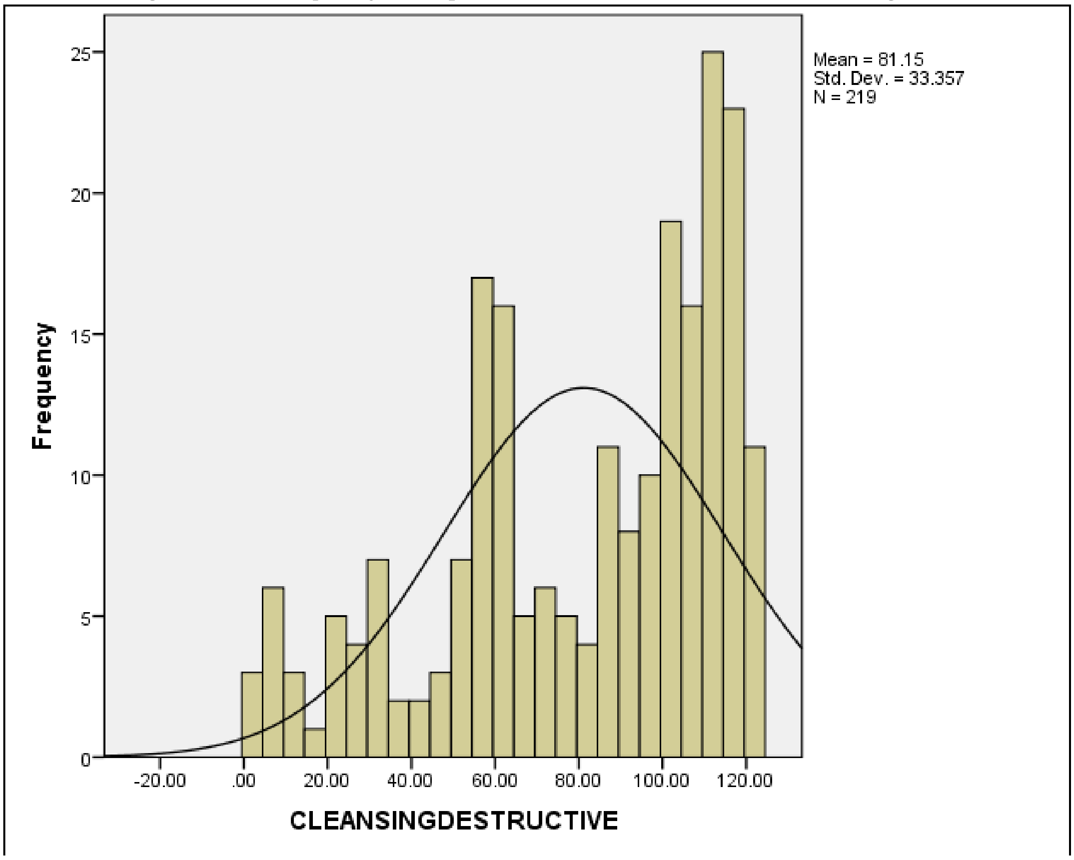
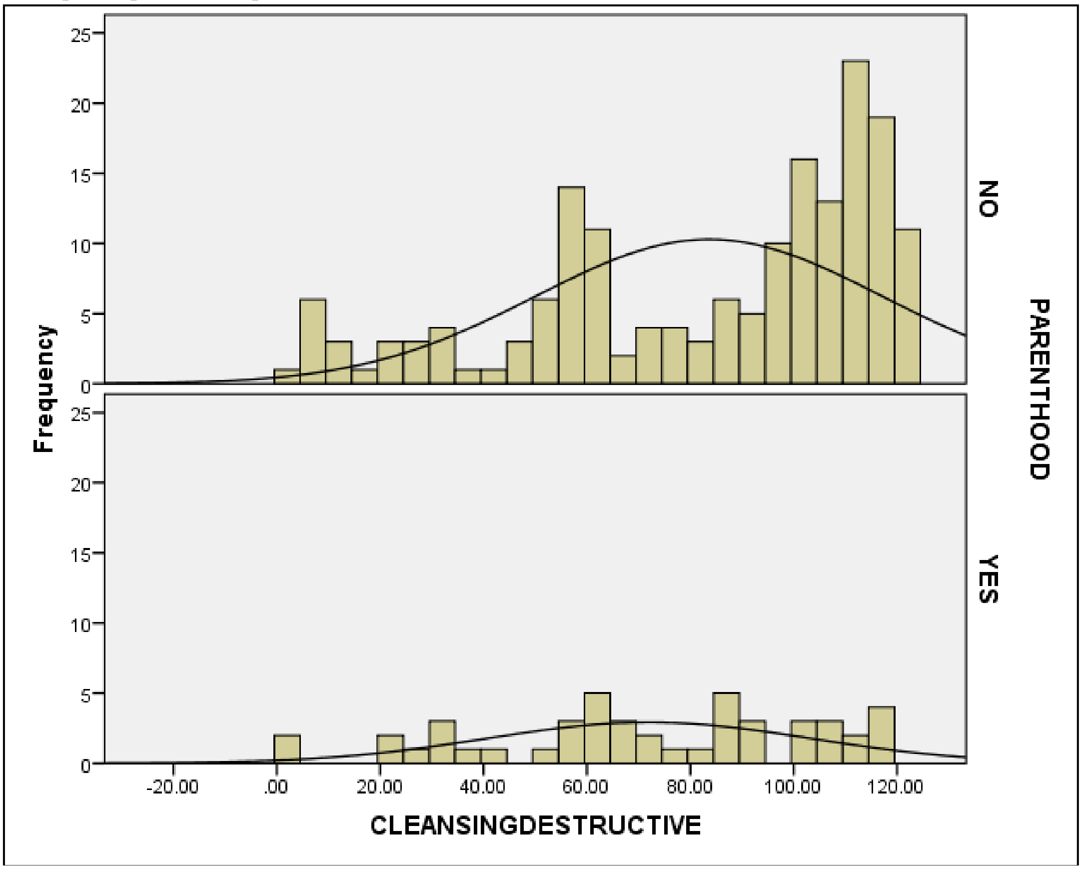


Figure 6.68: A histogram of the frequency of responses from the NBA cohort to CleansingDestructive filtered by whether participants were parents or not

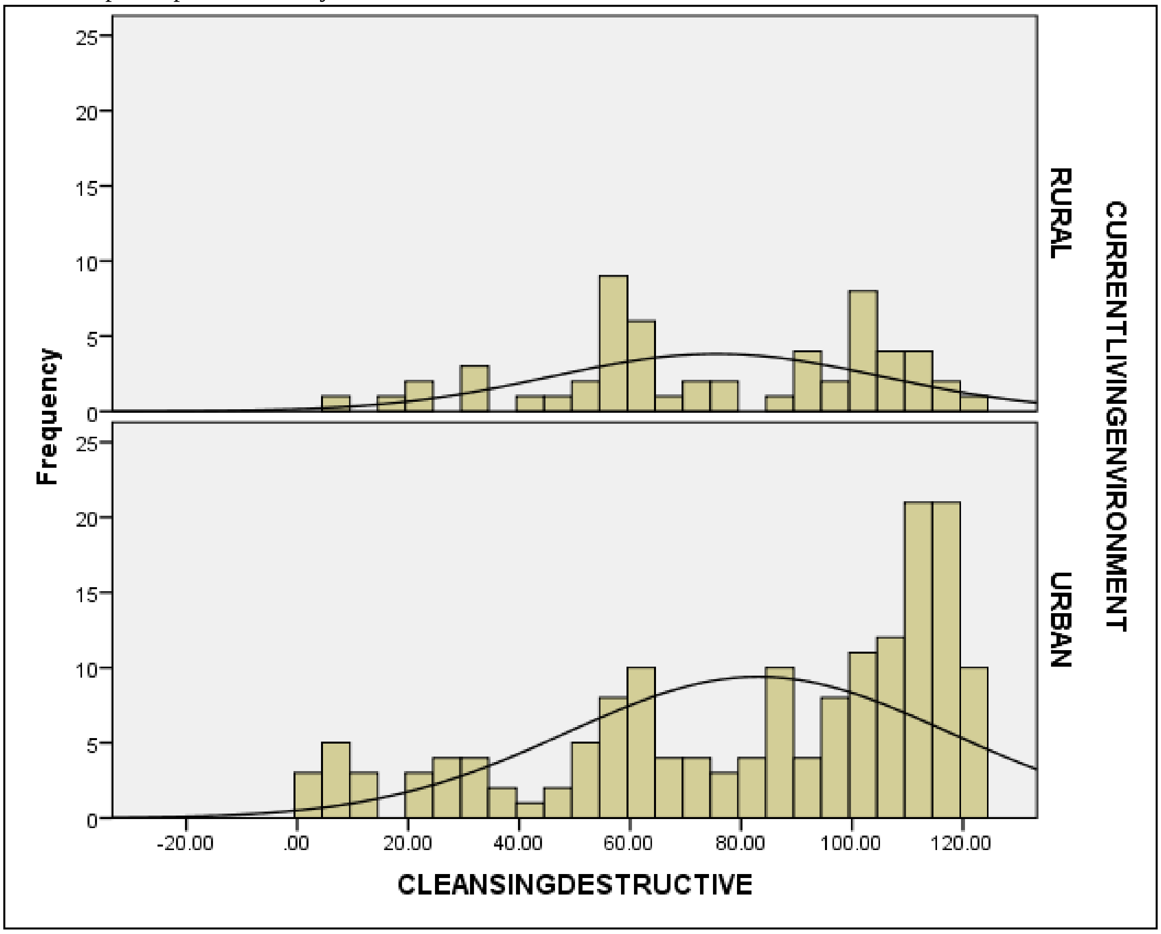


	SEX	N	Mean Rank		
CleansingDestructive	MALE	152	106.40	Chi-Square	1.603
	FEMALE	67	118.16	df	1
	Total	219		Asymp. Sig.	0.205
	BURNTORNOT	N	Mean Rank		
CleansingDestructive	no	49	117.41	Chi-Square	0.863
	yes	170	107.86	df	1
	Total	219		Asymp. Sig.	0.353
	PARENTHOOD	N	Mean Rank		
CleansingDestructive	NO	173	115.40	Chi-Square	5.988
	YES	46	89.68	df	1
	Total	219		Asymp. Sig.	0.014
	NewAge	N	Mean Rank		
CleansingDestructive	18-24	142	113.29		
	25-34	52	109.38	Chi-Square	2.852
	35-44	15	95.20	df	5
	45-54	6	98.50	Asymp. Sig.	0.723
	55-64	2	87.50		
	65+	2	61.00		
	Total	219			
	Smokingstatus	N	Mean Rank		
CleansingDestructive	never smoked	188	113.24	Chi-Square	3.968
	ex-smoker	21	95.88	df	2
	current smoker	10	78.75	Asymp. Sig.	0.138
	Total				
	UNDER10LIVINGENVIRONMENT	N	Mean Rank		
CleansingDestructive	RURAL	159	105.03	Chi-Square	3.574
	URBAN	60	123.18	df	1
	Total	219		Asymp. Sig.	0.059
	ADOLESCENTLIVINGENVIRONMENT	N	Mean Rank		
CleansingDestructive	RURAL	108	107.33	Chi-Square	0.378
	URBAN	111	112.59	df	1
	Total	209		Asymp. Sig.	0.539
	CURRENTLIVINGENVIRONMENT	N	Mean Rank		
CleansingDestructive	RURAL	57	94.54	Chi-Square	4.587
	URBAN	162	115.44	df	1
	Total	219		Asymp. Sig.	0.032
	FireUseCatNEW	N	Mean Rank		
CleansingDestructive	Low Usage (1-3)	4	100.13	Chi-Square	0.576
	Medium Usage (4-6)	61	114.93	df	2
	High Usage (7-10)	154	108.31	Asymp. Sig.	0.750

Table 6.43: Kruskal-Wallis test data with CleansingDestructive as the test variable and a number of demographic grouping variables

Kruskal-Wallis testing identified two statistically significant relationships within the responses to the CleansingDestructive word-pair for the NBA cohort (parenthood and current living environment) (Table. 6.43); with a further variable (under 10 living environment) being significant at the 94% confidence level. It is perhaps surprising that the variable ‘Parenthood’ was calculated to be significant (χ^2 = 5.988, p = 0.014) due to the ~80/20 ratio between ‘not parents’ and ’parents’. However the data shows that parents perceive fire as much more cleansing than destructive (by more than 25 Mean Rank points [Table. 6.43]) a relationship easily visible within Fig. 6.69. It appears that the very large mode identified previously in the 100-120 range is almost entirely composed of non-parents. Furthermore this relationship is not down to the age of the respondents, as age was found to not be significant, or even nearly significant (χ^2 = 2.852, p = 0.723) (Table. 6.43).

Figure 6.69: A histogram of the frequency of responses from the NBA cohort to CleansingDestructive filtered by whether participants currently live in a rural or urban environment



The current living environment of a participant was also found to be statistically significant (χ^2 = 4.587, p = 0.032). Rural inhabitants perceive fire as more cleansing than urban residents; this is not surprising given the role often played by fire within African agricultural practices. The relationship between rural residents viewing fire as more cleansing than urban residents is observable across all three ‘living environment variables’, but the relationship is only significant at the 95% confidence level within the ‘current living environment’ variable.

Non-Batwa African Summary

None of the datasets generated by the NBA cohort conformed to what would be expected from a normal distribution. The highest number of statistically significant relationships was identified for the demographic variables ‘parenthood’ and ‘current living environment’ which were both found to have three statistically significant relationships (Table. 6.44). ‘Adolescent living environment’ and ‘fire-use experience’ were each observed to have one statistically significant relationship; for all other demographic variables no statistically significant relationships were identified for the NBA cohort of this study using Kruskal-Wallis tests. SafeScary was observed to have the most number of statistically significant relationships computed from the nine grouping variables tested for, with three significant relationships (‘adolescent living environment’, ‘current living environment’ and ‘fire-use experience’); Cleansing Destructive was identified as having two statistically significant relationships (‘parenthood’ and ‘current living environment’) while ProtectiveRisky(rev) [‘current living environment’], SocialViolent(rev) [‘parenthood’] and FriendlyFearsome [‘parenthood’] were all found to have one statistically significant relationships; (Table. 6.44). The other six word-pairs were all found to have zero statistically significant relationships.

The demographic variables: i) Sex; ii) Burnt or not; iii) Age; iv) Smoking status; and, v) Under 10 Living Environment were not found to have any statistically significant relationships (Table. 6.44). After a brief scan of the ratios between the different demographic responses it may appear that insufficient balance exists between some groups to generate statistically significant relationships (Table. 6.31) but this may not be accurate. For example 'Burnt or Not' has a ~22%/78% (No/Yes) ratio within the NBA cohort and no identified statistically significant relationships, while a 79%/21% (No/Yes) ratio exists within the NBA data for 'Parenthood' which had 3/11 statistically significant relationships. Additionally 'Under 10 living Environment' (73%/27%, rural/urban) was never significant (although CleansingDestructive was almost significant [p = 0.059] – Table. 6.43]) but 'Current living environment' (26%/74%, rural/urban) was found to be significant within the datasets of three word-pairs. Therefore other reasons must be sought to explain the lack of significance for some variables. It is however highly probable that for the variables 'Age' and 'Smoking Status' (which had very uneven spreads) the spread of demographic data was not balanced enough (e.g. 85.8% of 'never-smokers'), coupled with the highly nuanced differences in results generated from the NBA cohort, to generate statistical significance.

Number of statistically significant relationships										
Variable	Sex	Burnt Or Not	Parenthood	Age	Smoking Status	Under 10 living Environment	Adolescent living Environment	Current Living Environment	Fire-use Experience	TOTAL
PROTECTIVERISKY(rev)	N	N	N	N	N	N	N	Y	N	1
EXCITINGDANGEROUS	N	N	N	N	N	N	N	N	N	0
WARMINGBURNING(rev)	N	N	N	N	N	N	N	N	N	0
SOCIALVIOLENT(rev)	N	N	Y	N	N	N	N	N	N	1
SAFESCARY	N	N	N	N	N	N	Y	Y	Y	3
USEFULHAZARDOUS(rev)	N	N	N	N	N	N	N	N	N	0
COMFORTINGSTRESSFUL	N	N	N	N	N	N	N	N	N	0
FRIENDLYFEARSOME	N	N	Y	N	N	N	N	N	N	1
GIFTTHREAT	N	N	N	N	N	N	N	N	N	0
ATTRACTINGREPELLING	N	N	N	N	N	N	N	N	N	0
CLEANSINGDESTRUCTIVE	N	N	Y	N	N	N	N	Y	N	2
TOTAL	0	0	3	0	0	0	1	3	1	8

Table 6.44: A summary of the number of statistically significant relationships obtained by Kruskal-Wallis testing data collected from the Non-Batwa African cohort (95% confidence level

Why these analyses are presented in individual cohorts

Initially all analyses were conducted using the entire population surveyed within this study (N = 661). Nearly every single analysis showed high levels of significance (very often p = <0.001). However when a comparison was made of the demographics (e.g. age, gender, smoking status and current living environment) it became obvious that in fact ‘apples and pears’ were being compared. Subsequent Chi-Squared analysis shows high levels of statistical difference between **EVERY** demographic variable that data was collected for with **EVERY** test showing ‘p-values’ of <0.001 (Table. 6.45). It therefore became evident that each community would need to be analysed separately prior to a more holistic synthesis of the results being made. The reason for this is that the initial high levels of significance identified during ‘whole database analysis was possibly just picking up underlying statistical differences between communities rather than real trends or patterns within the perception of fire of study participants. The fact that real and significant differences do clearly exist within the way that different communities frame and perceive fire further complicated this matter. These real and highly significant differences between the mean responses of communities are discussed after an overall summary of results from the Kruskal-Wallis Tests.

Overall Summary of Kruskal-Wallis Tests on the Word-Pairs from Q1

In total across the three cohorts thirty-five statistically significant relationships were identified from Kruskal-Wallis testing of the eleven word-pairs (UK = 21 [Table. 6.14]; Batwa = 6; [Table. 6.30]; NBA = 8 [Table. 6.44]). It is postulated here that the Batwa and NBA totals would have been greater were the sampling to have picked up greater variation in variables such as past and current living environments and the breadth of a respondent’s fire-use experience. Tables 6.46 and 6.47summarise whether any significance was observed

Category	Variable	UK	Batwa	Non-Batwa African	χ^2	P
	N	217	225	219	57.343	<0.001
		%	%	%		
Sex	Male	43.8	34.7	69.4		
	Female	56.2	65.3	30.6		
Parenthood	No children	47.9	18.7	79.0	249.787	<0.001
	Children under age 18	22.6	72.0	18.3		
	Adult children	29.5	9.3	2.7		
New Age	18-24	21.7	33.3	64.8	153.846	<0.001
	25-34	18.4	29.8	23.7		
	35-44	16.6	16.9	6.8		
	45-54	12.9	10.2	2.7		
	55-64	17.1	6.2	0.9		
	65+	13.4	3.6	0.9		
Smoking status	Never smoked	53.9	24.4	85.8	218.008	<0.001
	Ex-smoker	35.5	29.3	9.6		
	Current smoker	10.6	46.2	4.6		
Burnt or not	No	54.4	20.4	22.4	72.788	<0.001
	Yes	45.6	79.6	77.6		
How badly burnt	Numbers burnt (not %)	99	179	170		
This data only looks at those who answered that they had been burnt	Slightly	82.8	52.5	78.2	42.132	<0.001
	Moderately	14.1	25.1	12.9		
	Severely	3.0	22.3	8.8		
Fire-uses individual (% yes)	Keeping insects away	33.6	96.9	61.6	193.984	<0.001
	Cooking food	94.5	100.0	100.0	25.007	<0.001
	Keeping warm	96.3	100.0	95.6	24.705	<0.001
	Lighting	64.1	100.0	95.4	145.380	<0.001
	Signalling	4.1	96.4	34.7	395.152	<0.001
	Cleaning and cleansing	21.2	96.4	55.4	262.314	<0.001
	Boiling water	79.3	100.0	99.1	90.966	<0.001
	Killing plants	19.8	55.6	62.1	91.023	<0.001
	Burning rubbish	70.5	96.0	88.2	97.479	<0.001
	Making things	29.0	77.3	62.6	109.663	<0.001
Fire usage combined	Low Usage (1-3)	20.3	0	1.8	284.513	<0.001
	Medium Usage (4-6)	54.4	0.9	27.9		
	High Usage (7-10)	25.3	99.1	70.3		
Under 10 living environment (predominant)	Rural	28.6	96.0	66.1	230.031	<0.001
	Urban	71.4	4.0	33.9		
Age 10 to 18 living environment (predominant)	Rural	27.6	95.1	49.3	215.740	<0.001
	Urban	72.4	4.9	50.7		
Current living environment	Rural	22.6	95.6	26.0	302.082	<0.001
	Urban	77.4	4.4	74.0		

Table 6.45: A between communities Chi-Squared analysis of the frequencies of demographic data from the three cohorts surveyed within this study (UK, Batwa and NBA)

within the different cohort's demographic variables. No demographic variable was observed to have provided statistically significant results from every cohort (Table. 6.46). However two demographic variables provided statistically significant results from two cohorts: the age of participants (UK and Batwa) and whether they were parents or not (UK and NBA); it is conceivable that if the age spread of the NBA cohort had been more even then perhaps 'Age' would have been significant at some point of the analysis in all three cohorts. Likewise if more Batwa had yet to produce children (than the 18.7% recorded within this study) then perhaps statistically significant results would have been generated. Furthermore the breadth of fire-use experience also identified statistically significant results from two cohorts (UK and NBA) with the Batwa unable to be tested for it due to more than 99% (223 out of 225) respondents falling into the 'high-usage' category (Table 6.15).

	Statistically Significant Relationships?									
Variable	Sex	Burnt Or Not	Parenthood	Age	Smoking Status	Under 10 living Environment	Adolescent living Environment	Current Living Environment	Fire-use Experience	TOTAL
UK	Y	Y	Y	Y	N	N	N	N	Y	5/9
Batwa	N	N	N	Y	Y	N/A	N/A	N/A	N/A	2/5
NBA	N	N	Y	N	N	N	Y	Y	Y	4/9
No. of Cohorts with statistically significant relationships	1	1	2	2	1	0	1	1	2	11

Table 6.46: A summary of the location of statistically significant relationships obtained by Kruskal-Wallis testing data collected from the three different cohorts of this study (UK, Batwa and NBA)

Only one demographic variable, 'Under 10 living environment' was found to have produced no statistically significant results from this study. However this was only from two cohorts (as the predominantly rural nature of the Batwa meant that testing was not applicable), and as was discussed in the NBA section, confidence *was* identified at the 94%, but not the 95%, level. Interestingly 'sex' and whether a respondent was burnt or not were not found to be significant at all within either of the African cohorts. Additionally no demographic variable was identified to be statistically significant within both African cohorts (Tables. 6.46 and 6.47). Clearly showing that in these cohorts different factors determine the framing of fire; thus confirming how fundamentally dissimilar these societies are. Past or current living environments were not found to be significant at all in the UK sample despite the ratios of ~25%/75% (Table. 6.1) being amenable to statistical significance being plausibly identifiable. Of the eleven word-pairs used in Q1, two were identified as having statistically significant relationships with demographic variables from all three cohorts (ProtectiveRisky[rev] and FriendlyFearsome) (Table. 6.47). Furthermore Table 6.48 shows that: i) five word-pairs had statistically significant relationships with demographic variables from two cohorts

	Matrix of Statistically Significant Relationships (SSRs)										
Variable	Sex	Burnt Or Not	Parenthood	Age	Smoking Status	Under 10 living Environment	Adolescent living Environment	Current Living Environment	Fire-use Experience	TOTAL (number of SSRs)	TOTAL (number of cohorts)
PROTECTIVERISKY(rev)	1	1		1/2	2			3	1	7	3
EXCITINGDANGEROUS		1	1	1/2					1	5	2
WARMINGBURNING(rev)										0	0
SOCIALVIOLENT(rev)	1		3	1					1	4	2
SAFESCARY		1	1	1			3	3	3	6	2
USEFULHAZARDOUS(rev)	1			2					1	3	2
COMFORTINGSTRESSFUL									1	1	1
FRIENDLYFEARSOME	1		3		2				1	4	3
GIFTTHREAT		1			2				1	3	2
ATTRACTINGREPELLING										0	0
CLEANSINGDESTRUCTIVE			3					3		2	1
TOTAL (number of SSRs)	4	4	5	7	3	0	1	3	8		
TOTAL (number of cohorts)	1	1	2	2	1	0	1	1	2		

Table 6.47: A matrix showing the location of statistically significant relationships obtained by Kruskal-Wallis testing data collected from individual analysis of all three cohorts (1 = UK Cohort; 2 = Batwa Cohort; 3 = NBA Cohort). Empty boxes denote where no statistically significant relationships were found between the responses to a specific word-pair from an individual cohort and response provided to a question about a particular demographic variable.

(ExcitingDangerous, SocialViolent[rev], SafeScary, UsefulHazardous[rev] and GiftThreat); ii) two word-pairs had statistically significant relationships with demographic variables from only one cohort (ComfortingStressful and CleansingDestructive); and, iii) two word-pairs were observed to have no statistically significant relationships with demographic variables from any cohort (Warmingburning and Attractingrepelling). It seems appropriate to note that of the five word-pairs with statistically significant relationships with demographic variables from two cohorts none of them have statistically significant relationships with demographic variables from the two African cohorts; they all consist of the UK cohort plus one African cohort. It also seems appropriate to reiterate that for the Batwa data only five of the nine demographic variables were able to be tested for significance (Table. 6.46). In chapter 7 conclusions and data generated from this study are used to test aspects of the Fear and Flames (FAF) hypothesis.

	Statistical significance or not			
Word-Pair	UK	Batwa	NBA	Total
PROTECTIVERISKY(rev)	Y	Y	Y	3
EXCITINGDANGEROUS	Y	Y	N	2
WARMINGBURNING(rev)	N	N	N	0
SOCIALVIOLENT(rev)	Y	N	Y	2
SAFESCARY	Y	N	Y	2
USEFULHAZARDOUS(rev)	Y	Y	N	2
COMFORTINGSTRESSFUL	Y	N	N	1
FRIENDLYFEARSOME	Y	Y	Y	3
GIFTTHREAT	Y	Y	N	2
ATTRACTINGREPELLING	N	N	N	0
CLEANSINGDESTRUCTIVE	N	N	Y	1
TOTAL	8	5	5	18

Table 6.48: A summary of the number of word-pairs from each cohort (UK, Batwa and NBA) from which statistically significant relationships were obtained by Kruskal-Wallis testing

Cross-Cultural Comparison of Means

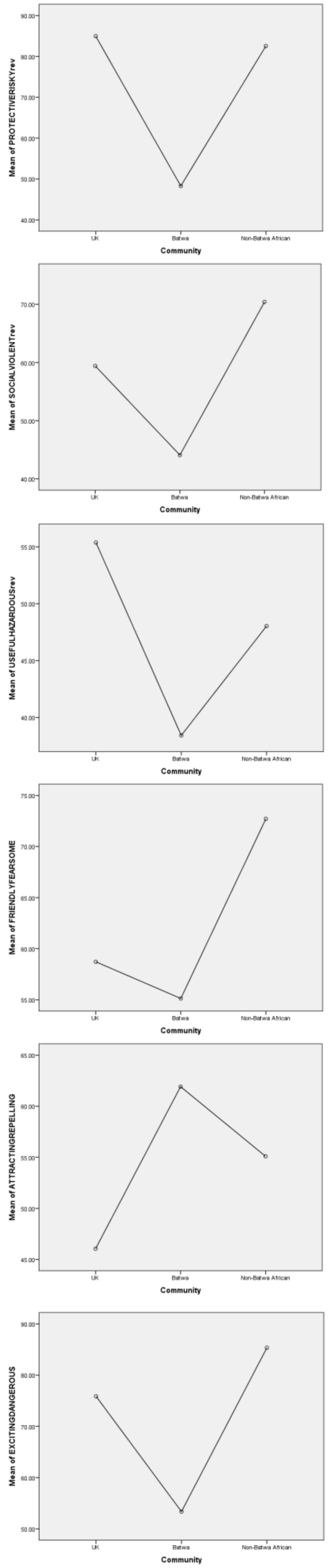
Means	UK N = 217		Batwa N = 225		NBA N = 219		All N= 661		Range of Means
Word-Pair	Mean	St. Dev.	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	
PROTECTIVERISKY(rev)	84.97	25.77	48.29	31.94	82.55	27.68	71.68	33.17	36.68
EXCITINGDANGEROUS	75.87	30.44	53.37	29.13	85.35	32.09	71.35	33.37	31.98
WARMINGBURNING(rev)	55.41	28.88	53.41	32.77	73.28	28.27	60.65	31.32	19.87
SOCIALVIOLENT(rev)	59.41	29.22	44.08	28.74	70.41	37.46	57.84	33.78	26.33
SAFESCARY	71.23	26.53	58.04	33.83	75.96	36.42	68.31	33.39	17.92
USEFULHAZARDOUS(rev)	55.37	28.33	38.43	28.31	48.04	31.53	47.18	30.19	16.94
COMFORTINGSTRESSFUL	38.29	25.07	60.12	32.39	60.81	35.44	53.18	32.94	22.52
FRIENDLYFEARSOME	58.72	26.89	55.12	35.02	72.71	33.33	62.13	32.82	17.59
GIFTTHREAT	60.00	27.82	55.44	34.37	62.70	36.06	59.34	33.05	7.26
ATTRACTINGREPELLING	46.05	25.30	61.92	35.01	55.10	32.65	54.45	31.94	15.87
CLEANSINGDESTRUCTIVE	78.18	24.24	60.75	34.14	81.15	33.36	73.23	32.21	20.40
Average	62.14	27.14	53.54	32.33	69.82	33.12	61.76	N/A	

Table 6.49: Mean averages from the eleven different word-pairs from QI from all three individual cohorts (UK, Batwa and NBA) and the overall Mean – Lowest Mean highlighted in green, highest in red (Average Means from each cohort are also included for reference at the bottom of the table)

Table 6.49 shows mean data from all three cohorts surveyed in this cross-cultural study; Fig 6.70 individually displays the average means of the eleven word-pairs so that relationships can be easily visualised. The overall mean average from all 7271 responses (N = 661 * 11) was 61.76 (Table 6.49) denoting that the overall average response framed fire in a very slightly negative way. In only 1/11 word-pair did all three cohorts provide a positive response (i.e. < 60) (UsefulHazardous [rev] – the average mean for this word-pair from all cohorts was 47.18 – the lowest overall average mean recorded) and in only 1/11 word-pairs (CleansingDestructive – the average mean for this word-pair from all cohorts was 73.23 – the highest overall average mean recorded) did all three cohorts provide a negative response (i.e. > 60) (Table 6.49); **therefore it is possible to say that overall across the three cohorts (N = 661) the most positive perception of fire is that it is useful, and the most negative is that fire is destructive.**

The word-pair with the greatest differences between the mean values of the three cohorts was ProtectiveRisky (rev) where the UK and NBA have similar results but the Batwa perceive fire in a much different way (UK = 84.97, Batwa = 48.29, NBA = 82.55). GiftThreat displays the greatest amount of similarity (Table 6.49). The far-right column in Table 6.49 shows the differences between the highest and lowest means (in this study termed the ‘range of means’). In all cases other than GiftThreat (7.26) the ‘range of means’ was > 15 (AttractingRepelling 15.87 [next lowest] → ProtectiveRisky [rev] 36.68 [highest overall ‘range of means’]); thus highlighting the distinct variation in results from the three cohorts. Trends which should allow clear conclusions to be drawn.

Data from the UK cohort shows that the UK, out of the three cohorts, viewed fire in the most balanced way (i.e. the mean value was closest to 60 – the UK mean value from all eleven word-pairs = 62.14). A mean value of slightly more than sixty denotes that the UK cohort overall perceive fire as slightly more negative than positive; however the nature of the results from the UK cohort show that UK respondents are aware of the positive and negative attributes and capacity of fire. In 2/11 word-pairs the UK mean was the lowest of all three cohorts (UK respondents view fire as relatively more comforting and more attracting than African respondents) and in 2/11 word-pairs the UK mean was the highest of all three cohorts (UK respondents view fire as relatively more risky and hazardous than African respondents). In the data from the other 7/11 word pairs the UK mean was greater than the Batwa mean but less than the NBA mean. Interestingly the standard deviations within the UK data were considerably lower than those from the Batwa and NBA cohorts (which had very similar results [Table 6.49]). This shows that the responses from the UK were the most ‘tightly clustered’ allowing greater confidence in the UK data; this is perhaps responsible for the twenty-one statistically significant results observed through the Kruskal-Wallis tests (Table.



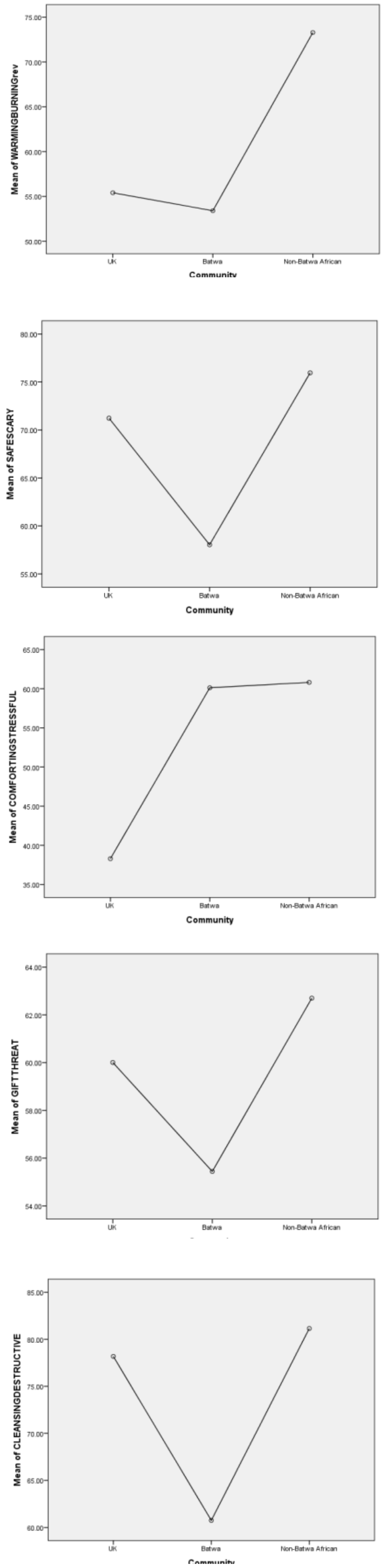


Figure 6.70: Plots of the Mean averages from the eleven different word-pairs from QI from all three individual cohorts (UK, Batwa and NBA)

6.14); the most from any of the three cohorts. It is now possible to say that **the mean data shows the UK cohort perceives fire more negatively than the Batwa, but more positively than the NBA**; these statements are supported by statistically significant data (Table. 6.49).

As can be clearly seen in Table 6.49 the Batwa had the most positive view of fire out of all three communities. The Batwa data shows that in 9/11 word-pairs the Batwa mean was the lowest and in only 1/11 was it the highest (AttractingRepelling); which is contrary to the expectation that the Batwa would have the strongest attraction to fire (see Chapter 7 for a thorough analysis of this point). The Batwa viewed fire as more: i) Protective; ii) Exciting; iii) Social; iv) Warming; v) Safe; vi) Useful; vii) Friendly; viii) (of a) Gift; and ix) Cleansing than respondents from both the UK and NBA cohorts (Table 6.49). Additionally not only was the average mean response from the Batwa the lowest average mean response from any cohort (being 8.60 points lower than the UK mean – Table 6.49) it was also the only average mean lower than 60.0. This means that of the three cohorts tested in this study **only the Batwa can be said to have a clearly positive view of fire**. The Batwa however appear to also be aware of the negative aspects of fire. They view fire as slightly stressful, repelling and destructive as opposed to comforting, attracting and cleansing.

The NBA data shows a very opposing set of results. Not only did the NBA cohort record the highest average mean of 69.82 denoting a much more negative ‘framing’ of fire than the other cohorts (more than 16.0 higher than the Batwa and more than 7.5 higher than the UK) which was more than 8.0 points higher than the overall average. Additionally in 8/11 cases the NBA mean was the highest from all three cohorts, and in zero cases was the NBA mean the lowest mean (Table 6.49). Results show clearly that the NBA cohort, despite having greater breadth of fire-use experience and living in more rural locations (both identified in this study as inferring more positive perceptions and attitudes to fire), perceive fire in more negative ways that the UK cohort (Table 6.49). Results show that in only 2/11 word-pairs did the NBA cohort register a mean of <60 (UsefulHazardous [rev] and AttractingRepelling) denoting a more positive than negative response to that word-pair. When the means from the three cohorts are plotted into simple diagrams (Fig. 6.70) a trend becomes very evident. The same ‘V’ pattern occurs clearly in 7/11 cases and a ‘V-like’ tick pattern is seen in a further 2/11 cases. **This consistent pattern shows that the Batwa mean is considerably less than, and different to, either the UK or NBA mean and provides clear visual evidence of different fire-based LOFs being present in the mindset of the Batwa as opposed to either the NBA or UK cohorts.**

RiskORProtect	Risky	Evenish	Protective	χ^2	P
UK	72.80%	14.70%	12.40%	215.659a	<0.001
Batwa	25.30%	7.60%	67.10%		
Non-Batwa African	68.00%	20.50%	11.40%		
Total	55.10%	14.20%	30.70%		
ExcitORDanger	Exciting	Evenish	Dangerous	χ^2	P
UK	22.60%	18.40%	59.00%	135.176a	<0.001
Batwa	64.90%	5.80%	29.30%		
Non-Batwa African	17.40%	15.10%	67.60%		
Total	35.20%	13.00%	51.70%		
BurningORWarming	Burning	Evenish	Warming	χ^2	P
UK	26.70%	25.30%	47.90%	108.872a	<0.001
Batwa	33.30%	8.90%	57.80%		
Non-Batwa African	47.90%	37.40%	14.60%		
Total	36.00%	23.80%	40.20%		
ViolentORSocial	Violent	Evenish	Social	χ^2	P
UK	31.30%	24.40%	44.20%	118.239a	<0.001
Batwa	20.40%	3.60%	76.00%		
Non-Batwa African	54.80%	12.30%	32.90%		
Total	35.40%	13.30%	51.30%		
SafeORscary	Safe	Evenish	Scary	χ^2	P
UK	25.30%	26.70%	47.90%	82.357a	<0.001
Batwa	55.60%	5.30%	39.10%		
Non-Batwa African	28.30%	11.00%	60.70%		
Total	36.60%	14.20%	49.20%		

HazardORuseful	Hazardous	Evenish	Useful	χ^2	P
UK	24.00%	30.90%	45.20%	83.769a	<0.001
Batwa	17.30%	3.60%	79.10%		
Non-Batwa African	25.10%	29.70%	45.20%		
Total	22.10%	21.20%	56.70%		
ComfortORStress	Comforting	Evenish	Stressful	χ^2	P
UK	71.40%	17.50%	11.10%	82.899a	<0.001
Batwa	52.90%	4.00%	43.10%		
Non-Batwa African	41.60%	16.90%	41.60%		
Total	55.20%	12.70%	32.10%		
FriendlyORfearsome	Friendly	Evenish	Fearsome	χ^2	
UK	39.20%	30.40%	30.40%	78.160a	<0.001
Batwa	58.70%	6.20%	35.10%		
Non-Batwa African	29.20%	16.40%	54.30%		
Total	42.50%	17.50%	39.90%		
GiftORthreat	A Gift	Evenish	A Threat	χ^2	P
UK	35.50%	33.20%	31.30%	61.744a	<0.001
Batwa	56.00%	5.30%	38.70%		
Non-Batwa African	39.70%	17.80%	42.50%		
Total	43.90%	18.60%	37.50%		
AttractORrepel	Attracting	Evenish	Repelling	χ^2	P
UK	61.30%	25.30%	13.40%	66.716a	<0.001
Batwa	48.00%	7.10%	44.90%		
Non-Batwa African	46.10%	23.30%	30.60%		
Total	51.70%	18.50%	29.80%		
CleansORdestructive	Cleansing	Evenish	Destructive	χ^2	P
UK	13.40%	23.00%	63.60%	81.300a	<0.001
Batwa	48.00%	8.90%	43.10%		
Non-Batwa African	19.60%	15.50%	64.80%		
Total	27.20%	15.70%	57.00%		

Table 6.50: By community ternary crosstabs analysis of word-pairs from question one (Evenish = 55 - 65)

Variable		All	UK	Batwa	NBA	NBA and UK
N		661	217	225	219	436
		%	%	%	%	%
Sex	Male	27.1	20.0	65.4	11.8	15.0
	Female	34.2	6.6	68.0	10.4	7.9
	χ^2	3.968	8.859	0.161	0.089	5.507
	P	0.046	0.003	0.688	0.765	0.025
Age group	18-24	29.5	14.9	74.7	10.6	11.6
	25-34	35.8	15.0	65.7	13.5	14.1
	35-44	38.2	11.1	76.3	6.7	9.8
	45-54	28.1	25.0	39.1	0.0	20.6
	55-64	18.9	2.7	64.3	0.0	2.6
	65+	20.5	6.9	50.0	100.0	12.9
	χ^2	10.075	8.651	12.732	17.203	6.37
	P	0.073	0.124	0.026	0.004	0.272

Smoking Status	Never smoked	17.5	11.1	52.7	11.2	11.1
	Ex-smoker	36.6	15.6	66.7	19.0	16.3
	Current smoker	58.4	8.7	75.0	0.0	6.1
	χ^2	81.526	1.184	8.094	2.509	3.063
	P	<0.001	0.553	0.017	0.285	0.216
Parenthood	No children	19.4	12.5	71.4	11.0	11.6
	Children under 18	49.4	20.4	67.9	10.0	15.7
	Adult children	18.7	6.3	52.4	33.3	8.6
	χ^2	66.457	5.107	2.465	2.962	2.013
	P	<0.001	0.078	0.292	0.227	0.365
Burnt or not?	No	23.5	8.5	71.7	14.3	10.2
	Yes	34.2	17.2	65.9	10.6	13.0
	χ^2	7.735	3.738	0.561	0.514	0.786
	P	0.005	0.053	0.454	0.473	0.375
Fire Usage	Low	6.3	4.5	N/A	25.0	6.3
	Medium	10.5	10.2	100	8.2	9.5
	High	41.9	23.6	66.8	12.3	15.3
	χ^2	73.659	9.404	0.989	1.484	4.757
	P	<0.001	0.009	0.320	0.476	0.093

Table 6.51: Proportion of cohort favouring protective (<55), from the protectiverisky word-pair, by sample characteristics derived through a Crosstabs analysis

To confirm that the results of the three cohorts are significantly different continuous data was transformed into ternary data and a crosstabs analysis was performed (Table 6.50). To create ternary data, responses in the range 1-54 were classed as having chosen the positive concept, 55-65 were classed as ‘Evenish’ (ambivalent or having a balanced view), and 66-120 were classed as having chosen the negative concept. All eleven word-pairs were identified using a Chi-Squared bivariate analysis to be significantly different to each other (P <0.001 for all word-pairs [Table 6.50]).

One word pair, protectiverisky, was identified through Kruskal-Wallis testing to have the most number of statistically significant relationships (7) spread across all three cohorts (UK=4; Batwa=2; NBA=1 [Table 6.47]). The analysis of the continuous data produced valuable results but also ambiguities. An alternative, simpler, approach would have been to pose binary questions (and then use a Crosstabs analysis); this is possible during data analysis as continuous data is easily reduced to a binary format. To delve further into any underlying trends continuous data was converted into binary data with two options; e.g.in the case of the protectiverisky word-pair responses in the range 1-54 were classed as having 'favoured protective' while the range 55-120 was classed as 'not protective' (Table 6.51). Without the nuanced responses of the 1-120 ranges continuous data most protectiverisky relationships are confirmed but with respect to the 'Age' variable different patterns emerge. Kruskal-Wallis testing had identified statistically significant in two cohorts (UK and Batwa). While a crosstabs analysis also identified statistically significant in two cohorts, in this case it was the Batwa and NBA cohorts (Table 6.51); Kruskal-Wallis testing had only generated a 'P'-value of 0.170 for the NBA cohort (Table 6.33).

Sex and 'burnt or not', both significant in the responses of the UK cohort to Kruskal-Wallis testing, are also significant in a crosstabs analysis; in both cases when the entire dataset (all three cohorts combined) is tested the result is also significant (Table. 6.52). This trend is mirrored when 'smoking status' and 'fire-use experience' data is analysed. Batwa 'smoking status' data is significant (as Kruskal-Wallis testing showed), as is the entire dataset when tested (Table. 6.51). This is also the case when UK 'fire-use experience' data is analysed.

By using the example of the protectiverisky word-pair it highlights the enormous value of the continuous data methodology employed in this study. The more nuanced nature of this methodology, relative to binary or ternary data, clearly allows correlations to be more accurately identified engendering greater confidence in results and, it is argued here, reducing the chances of Type I and Type II errors. The findings from the binary analysis of the protectiverisky word-pair have been provided purely as an example. No benefit can be seen in providing the same analysis from the other ten word pairs (which are thus omitted from this dissertation).

Acceptance or Rejection of Null Hypotheses

Null hypothesis A: No statistically significant differences exist between the fire-use-history of the three cohorts. **Rejected**

Table 6.47 clearly shows statistically significant differences between the fire-use-history of the three cohorts including: i) smoking levels; ii) prevalence of being injured by fire; and, iii) the breadth of a respondent's fire-use history.

Null hypothesis B: No statistically significant differences are visible between the fire-based LOFs of the three cohorts. **Rejected**

Table 6.49 clearly shows statistically significant differences are visible between the fire-based LOFs of the three cohorts with responses from 10/11 of the word-pairs from Q1 being significant at the 95% confidence level and 11/11 being significant at the 90% confidence level.

Null hypothesis C: That no statistically significant differences are visible between the fire-based LOFs of the three cohorts that can be explained by differences in fire-use behaviour or fire-use history; while variation may exist between different cohort's attitudes and mental relationships with fire these differences are not due to differences in fire-use behaviour or fire-use history or whether participants have had previous adverse interactions with fire.

Rejected

Table 6.45 clearly shows statistically significant differences are visible *within some cohorts* due to differences in fire-use behaviour or fire-use history or whether participants had had previous adverse interactions with fire.

Null hypothesis D: That whether a participant lives, or has lived, in a rural or urban environment has no statistically significant impact on the nature of their fire-based LOF.

Partially Rejected

While table 6.45 shows statistically significant differences are visible *within the NBA cohort* due to whether a participant lives, or has lived, in a rural or urban environment in both the 'adolescent' and 'current living environment' categories; this significance was not seen in the UK (undetected) or the Batwa data (not possible to be tested for). The 'under 10 living environment' category produced no statistically significant results from this study. However this was only from two cohorts (UK and NBA), and as was discussed in the NBA section, confidence *was* identified at the 94%, but not the 95%, level.

Null hypothesis E: That whether a participant has (or doesn't have) children, has no statistically significant impact on the nature of their fire-based LOF. **Partially Rejected**

Table 6.45 clearly shows statistically significant differences are only visible *within the UK and NBA cohorts* due to differences in whether a participant has (or doesn't have) children. This significance was not observed within the Batwa cohort; this was the cohort with the highest prevalence of participants with children (Table. 6.45).

Null hypothesis F: That whether a participant smokes (or has previously been a smoker) has no statistically significant impact on the nature of their fire-based LOF. **Partially Rejected**

Table 6.45 clearly shows statistically significant differences are visible *only within the Batwa cohort* due to whether a participant smokes (or has previously been a smoker). This significance was not observed within the UK and NBA cohorts; in the NBA cohort this was possibly due to the very small number of people who classified themselves as smokers or ex-smokers.

Null hypothesis G: That gender has no statistically significant impact on the nature of a person's fire-based LOF. **Partially Rejected**

Table 6.46 clearly shows statistically significant differences are visible *only within the UK cohort* due to gender, which was the cohort with the most balanced gender ratio (Table. 6.45). This significance was not observed within the two African cohorts.

Null hypothesis H: That age has no statistically significant impact on the nature of a person's fire-based LOF. **Partially Rejected**

Table 6.45 clearly shows statistically significant differences are only visible *within the UK and Batwa cohorts* due to age differences. This significance was not observed within the NBA cohort probably due to the highly 'slumped' nature of the NBA population pyramid.

Acceptance or rejection of postulates

Postulate 1: That those people with the most personal experience with fire will have the most positive attitude to fire. **Accepted**

Postulate 2: That the Batwa will have the most positive attitude to fire. Their fire-based LOF will, to a greater degree than the other communities' surveyed, recognise the positive attributes of fire. **Accepted**

Table 6.49 combined with Fig. 6.70 show clearly that the Batwa have the most positive attitude to fire, with mean responses being the lowest (most positive) in 9/11 occasions and highest (least positive) in 0/11 instances.

Postulate 3: That the UK cohort will have the least positive attitude to fire. Their fire-based LOF will, to a greater degree than the other communities' surveyed, recognise the negative attributes of fire. **Rejected**

Table 6.49 combined with Fig. 6.70 show clearly that the UK cohort does not have the least positive attitude to fire. Data from the NBA cohort frames fire in a more negative way than data from the UK cohort.

Postulate 4: That the results from the NBA cohort would be somewhere between the Batwa and the UK data; i.e. the NBA cohort would have a more positive attitude to fire than the UK population but more negative attitude to fire than the Batwa. **Rejected**

Table 6.49 combined with Fig. 6.70 show clearly that in fact the NBA cohort frames fire in the most negative way.

Postulate 5: People who live, or have lived, in rural areas will have a more positive attitude to fire than urban residents. **Partially accepted**

Where statistically significant results were identified this was the case; however the number of statistically significant results was low (four from the three variables combined) and were only observed within the NBA cohort.

Postulate 6: People who smoke will have a more positive attitude to fire than non-smokers. **Partially accepted**

Where statistically significant results were identified this was the case; however the number of statistically significant results was low (only 3) all of which were observed within the Batwa cohort.

Postulate 7: Despite the increased risk adversity expected around fire when a respondent has had a significant negative personal experience it is hypothesised that this will be mitigated by a natural (inherited) attraction to fire and will not be observed to be a significant factor within the data. **Partially accepted**

Where statistically significant results were identified this was the case; however statistically significant results were identified in only one cohort (UK cohort).

Postulate 8: Despite the increased risk adversity expected when a respondent has young children it is hypothesised that this will be mitigated by a natural (inherited) attraction to fire and will not be observed to be a significant factor within the data. **Partially accepted**

Where statistically significant results were identified this was the case; however statistically significant results were identified in only two cohorts (UK and NBA cohorts). The fire-related landscapes of fear (LOFs) of participants from the three cohorts were however observed to be significantly different thus allowing for in-depth dissection and discussion about why this may be the case and providing good quality data to apply to aspects of the FAF hypothesis (see Chapter 7).

Brief summary of Null Hypotheses and Postulates

None of the eight null hypotheses was accepted. Three were rejected outright (A, B and C) and five were 'partially rejected' (D, E, F, G and H). It was decided that a null hypothesis would be 'partly rejected' if a statistically significant relationship was observed in only one or two cohorts. The exception to this rule was with Null hypothesis C. In this instance it was rejected based on statistically significant relationships being observed in both the UK and NBA cohorts allied with the combination of facts that: i) nearly all of the Batwa cohort (>99%) were categorised in the highest group; and, ii) overall the Batwa had the most positive relationship with fire. Null hypothesis C equates to postulate '1' which was accepted. The null hypotheses D, E, F, G and H were all judged to be not quite so 'clear cut' as null hypothesis C and were thus classified as only 'partially rejected'.

Two postulates were accepted outright, four were 'partially accepted' and two were rejected outright. Two of the postulates that were 'partially accepted' (postulates 7 and 8) were classified thus due to statistically significantly relationships being identified in only one cohort (Postulate 7) or two cohorts (Postulate 8) but with at least four statistically significant results. While statistically significant results that were identified were in line with the expectations of the postulate the lack of statistically significant results from the Batwa cohort (in reality the most important cohort to this study's broader aim of illuminating ancient behavioural relics) results in less confidence being had in the concept and therefore the categorisation of these postulates as only being '*partially accepted*'. The other two postulates 'partially accepted' (postulates 5 and 6) were classified thus due to insufficient statistically significant relationships being identified in combination with statistically significant relationships being identified in only one cohort. The point of view taken here is that demographic imbalances within each individual cohort perhaps did not allow the full picture to be observed. Therefore, while in the remainder of this report discussion is presented based on the acceptance of these four postulates, it is here clearly stated that less than 100% confidence was generated in these findings (hence the 'partially accepted' status); however where statistically significant results were identified they were in line with the expectations of the postulate.

Postulates 2, 3 and 4 were all part of the same broader hypothesis, formulated prior to collecting data, that the NBA cohort (C3) would have attitudes to fire in between the Batwa (C2), who were postulated to have the most positive attitude to fire (postulate 2 - accepted) and the UK cohort (C1) postulated to have the least positive attitude to fire. The two postulates rejected outright (postulates 3 and 4) were rejected as it was the NBA cohort that quite clearly had the least positive attitude to fire (Table 6.49 and Fig. 6.70) and not the UK cohort. The Batwa cohort clearly had the most positive framing of fire (Table 6.48) and they also clearly had the most personal experience with fire (Table 6.45). However the NBA cohort, which was expected to occupy an intermediary position between the UK and Batwa cohorts, was instead identified as having clearly the most negative framing of fire.

Therefore the wider hypothesis that the Batwa would have the most positive fire-based LOF, followed by the non-Batwa Africans, with the UK population framing fire in the most negative way has been disproved and is rejected. Why this would be the case is simply a matter of conjecture. Some possible ideas are proposed here:

A) Differences in how this kind of methodology is approached by respondents from different cultures.

B) Significant demographic differences between cohorts (in effect were apples and oranges being compared?).

C) The obvious conclusion that the NBA cohort frame fire in a more negative way than the UK cohort despite having much greater familiarity with it (See Tables 6.1 and 6.31).

To test idea 'A' would require conducting further research on a different subject but using the same kind of methodology to see if inherent differences exist within how people from these different cultures approach this kind of questionnaire; therefore idea 'A' cannot be discounted here as this is beyond the scope and resources of this study.

To test idea 'B' would require returning to Uganda and recruiting a second NBA cohort with broader age and urban/rural split demographics (the UK cohort had the smallest standard deviations with the most tightly clustered data and is therefore deemed as imparting greater confidence to researchers) and analysing this data to see if similar trends and relationships are obtained; this is also beyond the scope and resources of this study.

However without undertaking efforts to address ideas ‘A’ and ‘B’ it is argued here that it is still possible to accept the conclusion that the NBA cohort frame fire in a more negative way despite having much greater familiarity with it. By identifying and clearly outlining ideas ‘A’ and ‘B’ it is hoped that this enables results, trends and conclusions to be viewed as more robust than if these ideas were omitted from this report.

None of these three ideas can be fully substantiated at present. While acknowledging that ideas ‘A’ and ‘B’ may have had some impact on the data, but cannot be corrected for here, in this study idea ‘C’ is viewed as just as parsimonious as ‘A and ‘B’ but allows three different perspectives to be taken; i) the UK cohort perceive fire in a more positive manner than imagined; ii) the NBA cohort perceive fire in a more negative way than imagined; or iii) a combination of the two.

Without wanting to devote too much space to discussing this, having spent two and a half years living in Uganda and being familiar with the nature of Ugandan systems such as electric wiring (e.g. the common use of medical syringes as ‘cheap light-switches’), poor consumer protection, the very high density of poor urban areas and the almost non-existent nature of fire and rescue services, it may be that the NBA cohort is much more aware of the actual real and present risks they personally face of fire and the potential for death and destruction than the UK population for whom the risks may be much more abstract in nature. This may have led to the NBA cohort being more negative in their attitude to fire than imagined prior to undertaking the research. The non-consumerist Batwa, very few of whom use electricity (those that do include the small urban population surveyed and a very small number with small solar units that power a single light fitting - those few rural Batwa with mobile phones invariably charge them intermittently in trading centres), lead a very different lifestyle from the NBA and so can be reasonably expected to frame risks very differently.

Therefore results obtained in this study are accepted as they are including the relative positions of the UK and NBA cohorts. This acknowledgment does not in any way however entirely condemn the results of this study and stop this data from being used to attempt to illuminate ancestral relationships. Overall a great deal of pride is felt in the high quantity of respondents recruited in this study and the high quality of data collected, particularly from the Batwa and NBA cohorts with their respective greater logistical and linguistic barriers that needed to be overcome. The data does clearly show that the Batwa have the (statistically significant) most positive attitude to fire, as postulated prior to fieldwork. Data also clearly highlighted the universal awareness and acknowledgment of the 'usefulness of fire'. These conclusions, and others, provide scope to hypothesise and speculate in an evidence-based manner on the nature of ancestral relationships, including the most ancient hominin-fire interactions and the adaptive selective pathways and pay-offs guiding the onset of hominin fire interactions.

Additional theoretical and practical issues faced

In addition to the issues surrounding the lack of frequency of experience of fire-use data mentioned previously a number of other issues or weaknesses may be present in this dataset. While it has already been explained that the word-pairs used in Q1 were specifically designed not to be exact opposites of each other but instead were differing perspectives on fire, perhaps a little more detail is required about exactly how these word-pairs were constructed. It is obvious that this would have significant impact on, and partly defined, the structure of the resulting data. If resources and time had allowed it would have been preferable to have mixed up the word pairs to see if the ‘popular’ choices would still have been ‘popular’ within different pairing (e.g. would *useful* still have been so strongly selected for if it had been paired with *risky* or *dangerous*). This would have made data collection and data analysis much more complex and time consuming but it is believed would significantly have helped improve the usefulness of statistical analysis such as hierarchical cluster analysis.

Word-pairings were constructed with the assistance of Prof. Mark Bellis an influential Public Health epidemiologist with a broad history of publications and research interests in aspects of human evolution. At the time of his input into this study Prof. Bellis was the Director of the Centre for Public Health Research at Liverpool John Moores University and was attempting to become a formal part of the supervisory team on this study. Prof. Bellis and his colleagues have considerable experience of constructing questionnaire based data collection and his help proved invaluable. Taking advice from this source the first questionnaire, including the initial word-pairs (which were then later only slightly modified) was constructed and then piloted. As no-one had previously undertaken research of this nature it was not possible to refer to published material to address the construction of the word-pairs.

Another issue worthy of mention is the impact of the regularity of fire experience on the polarisation of results. It could be construed that the more frequent a respondent’s fire-use was then the greater the opportunity would be for emotional responses to become firmly entrenched; obviously this assumes that each experience of fire is somewhat similar. This might be partly responsible for the very positive framing of fire observed in the (very regularly interacting with fire) Batwa. If the depth, and not just the breadth, of fire-use experience had been collected then this idea could have been explored more fully.

While the UK data was most tightly clustered (deduced by the distinctly smaller standard deviations compared to the African data) it was the African data that was, on average, most distal from the centrepoint (Table 6.49). While the Batwa can be classified as being highly culturally homogenous (i.e. one language and very similar culture and living conditions) the UK and NBA cohorts could be classified as much more culturally homogenous (although this is more definite for the NBA than the UK due to the nature of the data collection methods used). It cannot be discounted that the level of cultural homogeneity/heterogeneity may have impacted on the nature of responses received. However if this was a controlling factor then it may be expected that the NBA cohort (relatively highly culturally hetergenous) would have had less distinct results. Perhaps if further studies are undertaken some level of testing can take place to further explore this topic.

Chapter 7 – Applying survey data to tenets of the Fear and Flames Hypothesis

"Until the past century or so, fire was a near universal presence in human life. Working fires cooked, warmed, enlightened, entertained, worshipped and transmuted dross substances and landscapes into usable goods and habitats. Fire was everywhere. The first act of a day was to kindle a fire; the last act, to bank the coals; and in between, fire was a constant companion. Humanity's power was ultimately a fire power. Anything that so shaped their quotidian world enters the understanding of that world and is abstracted into the world beyond." Pyne 2016

Discussion and Evaluation

The analysis of modern attitudes towards fire presented in the previous two chapters is one of the first of its kind, and perhaps the first (although see Murray et al. 2015 *passim*). This chapter presents an evaluation of the key points that emerged from results (presented in Chapter 6) and aims to relate them to broader issues in human evolution and fire control with particular emphasis on the role of behavioural plasticity and adaptability in the initial uptake of hominin fire-use. In this chapter key fieldwork findings are discussed and explanations are proposed. In addition inferences are made about the nature of ancient hominin evolutionary adaptive relationships with fire.

The Fear and Flames (FAF) hypothesis proposes that psychological relationships with fire created and driven by 'landscape of fear' (LOF) affordances lie at the heart of hominin fire relationships. Therefore a close affinity with and a positive attitude to fire would be expected in modern populations even in situations where, due to risk factors such as having previous negative experiences with fire, it might lead to an aversion or negative framing of fire. FAF predicts that a positive framing of fire is present where people have little or no personal experience with fire but is envisaged to be strongest in people with lots of fire interactions.

Predicting results was never going to be simple as researchers had no prior experience of working with the unique survey methodology used in this study. In addition to this, risk-related attitudes to fire have not previously been tested for and published, therefore no prior data exists to compare with or test against. Beyond broad predictions such as ‘the Batwa would have the most positive attitude to fire’ specific numerical predictions were not made. For example it was never predicted that the mean value of any particular word-pair in any cohort would be ‘x’ or ‘y’, as the nature of responses to the kind of continuous scale offered to respondents was not deemed predictable. Of those pre-survey predictions that were made, not all were realised. However a number of key predictions were realised that can prove valuable to how researchers view both modern attitudes to fire and the evolutionary history of hominin fire-use, proposed here to be indelibly inter-linked.

Clear statistically significant differences were seen within and between the three cohorts. Overall the three most negative attributes of fire were that it is destructive, risky and dangerous and the three most positive attributes associated with fire are that it was comforting, useful and attractive (Table 7.1). It was postulated pre-survey that a universal attraction to fire would be observed in the results; instead however it is the universal ‘usefulness’ of fire that stands out within the results (results from the usefulhazardous word-pair show that this was the only word-pair to have a mean value of < 60 for all three cohorts, and it also produced the lowest overall mean from the eleven word-pairs [Table 7.1]). The only word-pair to have a mean of > 60 for all three cohorts was cleansingdestructive, which highlights that all three cohorts were aware of the dangers of fire and ranked this more highly than the cleansing capacity of fire.

A range of different demographic factors was seen to influence within-cohort trends in addition to the clear and important cross-cohort trend that greater personal experience of fire correlates to a more positive attitude to, and framing of, fire. This acknowledgment links well with the cross-cultural framing of fire as 'useful'. The result that was most removed from pre-survey predictions is that the UK cohort would have the least positive framing of fire (and that the NBA position would lie between the UK and Batwa cohorts). Instead the NBA cohort clearly had the most negative framing of fire (the potential reasons for this have already been discussed in detail at the end of Chapter 6). Additionally the attractingrepelling word-pair Batwa 'anomaly' (of the three cohorts the Batwa had the highest mean response - discussed in detail in this chapter) is highlighted as being very different from pre-survey predictions.

As mentioned in Chapter 4, to fully reconstruct an accurate Plio-Pleistocene hominin palaeolandscape of fear (PLOF) would require increased palaeoclimatic and palaeoecological knowledge/resolution, coupled with a much greater resolution of ancestral behaviours, than researchers currently possess. Nevertheless having clearly noted these provisos and stating here that '***fully and entirely accurately reconstructing hominin PLOFs is clearly not yet possible***', in this chapter a number of evidence-based inferences of hominin PLOFs will be made based on the results of the research undertaken as part of this study that sampled and ascertained the risk-related attitudes and feelings that modern humans have towards fire.

Addressing the specific research questions posed in Chapter 5

Before these are introduced and dissected the nine specific research questions posed in Chapter 5 (that led to the formulation of the null hypotheses and postulates) are briefly addressed. As it is necessary in this chapter to refer frequently to the key findings from the research, the mean values of the three cohorts (Table 6.49) and the data summary of the word-pair analyses (Table 6.47) are presented again and retitled as Tables 7.1 and 7.2 respectively. A short discussion regarding the validity of this approach and whether the results, relationships and trends presented in Chapter 6 can actually be ascribed to ancestral behavioural relics is provided in Chapter 8.

How is fire perceived by these modern populations? How does fire fit into the modern human landscape of fear?

The populations sampled provide some insights into these issues. Fire appears to be framed most positively by people with the broadest personal interactions with it suggesting that the benefits of fire while not necessarily outweighing the risks of fire are at least perceived as doing so. Fire is framed broadly positively in the Batwa cohort, less so in the UK, and most negatively in the NBA cohort (Table 7.1). The data does not show an absolutely clear ‘universal attraction to fire’ but does show that fire in many cases is more positively framed than might be expected given the risks associated with fire and the (in the UK cohort) relatively low levels of personal experience. At the forefront of the initial survey design phase was the concept of a ‘universal human attraction to fire’ (this was ‘moved on from’ as it was thought too simplistic an idea that did not adequately map to a strong evolutionary adaptive selective force); in actuality the word-pair attractingrepelling was found to be one of only two word-pairs in which no statistically significant relationship was identified from any cohort (Table. 7.2), and it was also the only word-pair that the Batwa had the most negative framing for (this apparent ‘anomaly’ is discussed in detail later in this chapter). The fact that so many statistically significant relationships were identified within and between cohorts provides significant amounts of material with which to approach the subject of hominin fire-use history and the nature of the earliest hominin fire interactions.

Do attitudinal differences exist between these cultures within the 'fire-based Landscapes of Fear' created by modern people

Clear and statistically significant differences were consistently observed between the fire-based landscapes of fear generated by the three cohorts (e.g. data presented in Tables 6.49 and 6.50). These differences can be argued to show how recent cultural changes have significantly altered how humans frame and view fire and therefore point towards the nature of ancestral fire relationships. Perhaps of particular interest are the stark differences in results observed between the two African cohorts. **This clearly highlights the fact that it is not just differences in climate and habitat that has driven the observed attitudinal differences between cohorts, as may be invoked for differences between the UK and Batwa cohorts, but cultural factors as well**. While not all trends observed within the data are as predicted, researchers exceeded expectations as to both the quantity and quality of data collected, particularly from the two African cohorts.

Do these urban and rural populations differ in their attitudes to fire?

Interpreting the answer to this question requires some care. The Batwa cohort was unable to be tested for intra-cohort significance in this aspect as the Batwa are still very much a community of rural inhabitants; however the Batwa results are still especially useful for inter-cohort comparisons as they are clearly a very rural community and had distinctly different attitudes to fire than urban populations. The NBA cohort did show some statistically significant relationships but relationships are not as clear as was hypothesised that they would be prior to data collection; in all NBA cases (4/33) where statistical significance was observed rural inhabitants were associated with a more positive framing of fire than urban inhabitants (Table 7.2).

The UK cohort did not show any statistically significant relationships where there was ample opportunity for relationships to occur (i.e. no statistically obvious reasons exist for why no relationships were identified); perhaps simply ascertaining and then comparing respondents with different living environments does not equate to the comparison of people with distinctly different lifestyles. Living in a rural environment in a highly developed country does not necessarily equate to having a very rural (or traditional) lifestyle e.g. farming. Many people in the UK commute to urban areas for work but live in rural areas; would they be expected to have a significantly different framing of fire to urban residents? Answering this question is not the focus of this study, but this discussion does highlight some of the potential pitfalls of relying on very simple demographic questions. The alternative, i.e. asking many questions to increase data precision, would create exhaustive questionnaires, unwieldy databases and would make data collection and analysis difficult, highly time-consuming and resource intensive; it would also make participant recruitment more difficult.

Do these hunter-gatherer and non-hunter-gatherer attitudes and perceptions of fire differ significantly?

Yes: within the scope of the survey hunter-gatherer and non-hunter-gatherer attitudes and perceptions of fire do differ significantly. The Batwa collectively had a statistically significant more positive framing of fire than the other two cohorts (Table. 7.1) in line with the expectations of the Fear and Flames Hypothesis, with the glaring exception of the word-pair attractingrepelling.

	UK N = 217		Batwa N = 225		NBA N = 219		All N= 661		Range of Means
Word-Pair	Mean	St. Dev.	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	
PROTECTIVERISKY(rev)	84.97	25.77	48.29	31.94	82.55	27.68	71.68	33.17	36.68
EXCITINGDANGEROUS	75.87	30.44	53.37	29.13	85.35	32.09	71.35	33.37	31.98
WARMINGBURNING(rev)	55.41	28.88	53.41	32.77	73.28	28.27	60.65	31.32	19.87
SOCIALVIOLENT(rev)	59.41	29.22	44.08	28.74	70.41	37.46	57.84	33.78	26.33
SAFESCARY	71.23	26.53	58.04	33.83	75.96	36.42	68.31	33.39	17.92
USEFULHAZARDOUS(rev)	55.37	28.33	38.43	28.31	48.04	31.53	47.18	30.19	16.94
COMFORTINGSTRESSFUL	38.29	25.07	60.12	32.39	60.81	35.44	53.18	32.94	22.52
FRIENDLYFEARSOME	58.72	26.89	55.12	35.02	72.71	33.33	62.13	32.82	17.59
GIFTTHREAT	60.00	27.82	55.44	34.37	62.70	36.06	59.34	33.05	7.26
ATTRACTINGREPELLING	46.05	25.30	61.92	35.01	55.10	32.65	54.45	31.94	15.87
CLEANSINGDESTRUCTIVE	78.18	24.24	60.75	34.14	81.15	33.36	73.23	32.21	20.40
Average Means	62.14	27.14	53.54	32.33	69.82	33.12	61.76	N/A	

Table 7.1: Mean averages from the eleven different word-pairs from QI from all three individual cohorts (UK, Batwa and Non-Batwa African) and the overall Mean – Lowest Mean highlighted in green, highest in red (Average Means from each cohort are also included for reference at the bottom of the table)

	Matrix of Statistically Significant Relationships (SSRs)										
Variable	Sex	Burnt Or Not	Parenthood	Age	Smoking Status	Under 10 living Environment	Adolescent living Environment	Current Living Environment	Fire-use Experience	TOTAL (number of SSRs)	TOTAL (number of cohorts)
PROTECTIVERISKY(rev)	1	1		1/2	2			3	1	7	3
EXCITINGDANGEROUS		1	1	1/2					1	5	2
WARMINGBURNING(rev)										0	0
SOCIALVIOLENT(rev)	1		3	1					1	4	2
SAFESCARY		1	1	1			3	3	3	6	2
USEFULHAZARDOUS(rev)	1			2					1	3	2
COMFORTINGSTRESSFUL									1	1	1
FRIENDLYFEARSOME	1		3		2				1	4	3
GIFTTHREAT		1			2				1	3	2
ATTRACTINGREPELLING										0	0
CLEANSINGDESTRUCTIVE			3					3		2	1
TOTAL (number of SSRs)	4	4	5	7	3	0	1	3	8		
TOTAL (number of cohorts)	1	1	2	2	1	0	1	1	2		

Table 7.2: A matrix showing the location of statistically significant relationships obtained by Kruskal-Wallis testing data collected from individual analysis of all three cohorts (1 = UK Cohort; 2 = Batwa Cohort; 3 = NBA Cohort). Empty boxes denote where no statistically significant relationships were found between the responses to a specific word-pair from an individual cohort and the response provided to a question about a particular demographic variable.

Do Batwa attitudes and perceptions of fire more closely resemble hypothesised ancestral relationships?

Yes, Batwa attitudes and perceptions of fire more closely resemble hypothesised ancestral relationships (see the final part of Chapter 4); with the exception that the Batwa did not associate fire strongly with the term ‘attracting’. While in this study only one hunter-gatherer society (or very recently hunter-gatherer society) was surveyed, and caution has to be exercised so as not to over-extrapolate the value of the data collected in this study, data does clearly show that people with lifeways and strategies that most closely resemble ancestral lifeways and strategies have the most positive framing and attitudes towards fire (as predicted). *However the opposite was not observed to be true*. The UK cohort, who could be cogently argued to be the most industrially developed and the most heavily culturally impacted by modern life, did not have the least positive framing and attitudes towards fire; the NBA cohort did. This finding hints at the complexity of factors that influence modern human attitudes to, and framing of, fire.

Does parenthood significantly change a respondent’s attitudes and perceptions of fire?

Within the UK and NBA cohorts whether a respondent was a parent or not was observed to have some impact on a respondent’s attitudes and perceptions of fire (Table 7.2), although the within-cohort trends were markedly different. In the UK cohort being a parent was associated with a more negative framing of fire (2/11 word-pairs), while in the NBA cohort being a parent was associated with a more positive framing of fire (3/11 word-pairs); no statistically significant relationships were observed within the Batwa cohort relating to parenthood, perhaps due to the perceived greater strength of community ties prevalent in Batwa society.

Does having received an injury from fire significantly alter a respondent's attitudes and perceptions of fire?

Within the UK cohort four statistically significant relationships were observed (4/11); in each case a respondent framed fire more favourably if they reported that they had previously been burnt. Statistically significant relationships were not observed in the other two cohorts. This was despite sufficient statistical power being present to identify relationships if they were there. While data was not collected from the UK and NBA cohorts regarding the background to self-recorded fire-injuries, the statistically significant relationships observed in the UK data may link in with the high prevalence of child and adolescent 'fire-play' identified in a number of studies conducted on adolescents from industrialised countries (e.g. Kolko et al. 2001, Pinsonneault 2002, Perrin-Wallqvist and Norlander 2003).

Fessler (2006) links this high prevalence of fire-play in western culture with the removal of 'mundane fires' from industrialised societies, as he suggests it is not identifiable in more traditional societies. It is easy to postulate a clear relationship between 'fire-play' and being burnt. While it may be a simplistic assumption to say that in the UK cohort being burnt would relate to 'playing with fire', while in African populations it is more likely that being burnt would relate to more practical activities, perhaps an element of truth exists. Those who are curious about fire and want to play with fire are probably more likely to have been burnt and also more likely to frame fire positively thus producing the data trends observed in the UK cohort. Curiosity about fire in infants, juveniles and adolescents, including the role of fire-play, is discussed in greater depth later in this chapter.

Is greater interaction with fire linked to an increased attraction for fire?

Yes – this relationship is clear in both the UK and NBA cohorts. Within these two cohorts eight statistically significant relationships were identified between the breadth of a respondent's fire-use history and their attitudes to fire (Table 7.2), the highest for any demographic variable. However in the Batwa cohort as significance was unable to be tested for (due to zero Batwa reporting low breadth of fire-use history and only two out of two hundred and twenty-five reporting a medium breadth of fire-use experience) no statistically significant relationships could be attributed to individual word-pairs. While the Batwa clearly had the 'most personal interaction with fire' and the 'most positive overall framing of fire', finding some way to statistically link these two statements seems important. **Therefore due to observations made during survey fieldwork the idea is here proposed that 'smoking status' can act as a proxy for the level of personal interaction with fire for the Batwa.** This is because, as opposed to the 99.1% of Batwa who grouped in the 'high fire-use experience' group, only 46.2% of Batwa classified themselves as current smokers (Table. 6.45); a statistic that allows for between-group significance to be tested for. It is noticeable within the results (Table 7.2) that 'smoking status' was statistically significant in 3/11 word-pairs for the Batwa; on each occasion current smokers viewed fire most positively.

Batwa current smokers were personally observed during this study to have the closest personal relationship with fire; personal observations showed that Batwa most often smoke around a fire, directly using the fire for ignition. A number of reasons might exist for this. Firstly most Batwa simply do not have ***any*** money; it is much cheaper to light a cigarette directly from a fire than to use a match or lighter. Secondly cigarettes are very expensive so most Batwa smoke home grown tobacco (often not fully dried) rolled in paper torn out of a school exercise book (the cheapest and most accessible source of paper). This does not burn well and requires frequent re-ignition. As a result Batwa who smoke have very close and frequent interactions with fire. In addition Batwa evening social time (not personally observed in this study but ascertained through direct conversations with Batwa translators and study participants) is often spent around a fire in the evening when, according to smokers, most smoking takes place (possibly due to the issues with ignition mentioned here). It is not being suggested *per se* that smoking status is representative of a person's framing of fire but that with specific respect to the Batwa culture it may represent a usable proxy. Within the Batwa data smoking status was seen to be a statistically significant correlative factor when other variables such as gender and age were not.

Any clear trends linking a greater interaction with fire to an increased attraction to fire can seemingly provide usable material to illuminate and frame the nature of the earliest hominin fire relationships.

Can observed statistical trends be evidence of ancient behavioural relics?

An important question to address in detail is: Is it really feasible to study the attitudes of (and relationships with) modern humans and fire in such a way that, if these are consistent with expectations, it can be concluded that 'fitness benefits generated within PLOF adaptations' was plausibly a significant factor in the initial formation of hominin fire relationships?

While acknowledging that only three different communities have been sampled in this study, and also that other (similar) communities may produce different results, data generated in this study may be the best data yet with which to formulate and support core tenets of the FAF hypothesis. Therefore the simple answer proposed here is yes (although see detailed critique of Evolutionary Psychology in Chapter 4).

If the theoretical foundations of this study are resilient then a modern LOF analysis should be seen as ‘over-fitting’ antecedent PLOFs. It is however explicitly acknowledged here that this methodology is not immune to the fact that, if data shows patterns and trends consistent with the hypothesised ancestral PLOF with visible clear fitness benefits (when comparing the PLOFs of ‘fire-using’ and ‘non fire-using’ groups) then this may not actually show behavioural relics; in effect producing a ‘type 1’ error. Other explanations may be available which fit the data just as well. For example more recent fire-use changes and adaptations may have impacted more strongly on how modern humans interact with, and view, their environments. These would include for example; i) very recent behavioural changes such as the switch to electricity as a primary source of fuel; or, ii) the uptake of agriculture and the aggregation of society into villages and urban areas which has been an ongoing process in some parts of the planet for the past 10,000 years and which has had such a marked behavioural impact on the recent evolutionary history of humans. However as FAF is based on the clear premise that fire-use was an integral part of the transition into *Homo,* then, in this study, it is proposed that basal neural architecture (or a system of defined neural networks), developed and imbedded at the onset of our genus, exists. In this chapter, where necessary, when a result from fieldwork is proposed as a behavioural relic, other explanations will also be outlined and considered.

One major issue worthy of consideration is that for (probably) the first time since humans became obligate fire-users, many humans, particularly those from economically more developed countries living in urban areas, are now materially disconnected from fire itself.

While combustion or electrical heating is an essential part of everyday modern life, be it inside our boilers or car engines, many people routinely do not make, cook with or sit by fires. Indeed for many people in the UK perhaps the closest they regularly come into direct contact with fire is when they light a cigarette. It is known that human relationships with fire and other aspects of their landscape are not only determined from the nature of the ‘behavioural relics’ or evolutionary ‘detritus’ that they possess (Kaplan 1987, Kaplan and Kaplan 1989) but also by, amongst others, the forces of personal experience and acculturation (Han 2007, Lohr 2007). Removing the impacts of acculturation will prove difficult but with a combination of: i) intelligent methodological design; ii) clear acknowledgment of the limitations of this approach; and iii) the appropriate deployment of statistical tests, some good quality insights may prove possible.

Modern humans from ‘economically more developed countries’ who live in urban areas have, as well as materially disconnecting from fire, in nearly all cases almost entirely removed themselves from inter-specific predation risk. Therefore attempting to infer aspects of evolutionary relationships to landscapes from these populations will prove difficult. For example the experience of fire had by a UK citizen will perhaps be to a much greater extent (than for a Plio-Pleistocene hominin following the tenets of FAF) be driven by socio-economic factors rather than be part of a risk reduction strategy. It would be expected that behavioural relics would be ‘strongest’ or ‘identified most easily’ in those societies that deploy lifestyles and foraging strategies on the same kind of landscapes and in the same kind of ways (obviously with significantly enhanced mechanical knowledge and a much broader toolkit) as hunter-gatherers did before the advent of agricultural. That is why in this study large amounts of time, effort and resources were invested in accessing and interviewing a large cohort of Ugandan Batwa who have a much closer personal relationship to fire and African mosaic woodland environments, with their associated risks.

It should be stressed that some degree of caution must be exercised when projecting aspects of modern human behaviour onto organisms with distinctly non-modern human sized brains (as per Wood and Strait 2004). It is not always advisable to use modern people as ancient analogues (Bunn 2001) especially as they may not necessarily be direct, unbroken descendants of more ancient ancestral hunter-gatherers (Marlowe 2005). Indeed it may be that only hunter-getherers who occupy marginal habitats (such as the Ugandan Batwa who traditionally inhabited mountainous rainforests) have survived (Wilmsen 1989, Marlowe 2005). Even those communities that still practice hunting and gathering may have been distinctly impacted on or influenced by neighbouring farming communities (Foley 1988). Hominin niches are to a large extent determined by access to technology and the way that technology is used (Marlowe 2005). The Ugandan Batwa clearly have access to a broader range of technology that ancient hominins and therefore quite categorically inhabit a very different niche.

However for some specific kinds of information hunter-gatherer groups (e.g. the Hadza and the Ju/'hoansi) have been successfully used as an appropriate way to clarify and elucidate some of the adaptations of ancient hominins, including early members of *Homo* (Bunn 2001, Marlowe 2005, Wiessner 2014). However it must be clearly stated that in this study what is being looked for are 'faint vestiges' of ancient behaviour that may be present in all humanity but that may be more easily and clearly identified in modern hunter-gatherers. What is definitiely not being assumed is that the Batwa can in any way act as direct ancient analogues or in any way directly embody any specific aspect of ancient hominin behaviour, thinking or relationship with an environmental externality like wildfire.

Summary of key statistically observed trends

Table 7.2 shows a number of clear trends that may have evolutionary adaptive significance. Perhaps the most clearly visible trend is that, without using ‘smoking status’ as a proxy for Batwa ‘fire-use experience’, no demographic variable was observed to be statistically significant in all three cohorts; therefore discussing ‘underlying universal reasons for modern human fire-related perceptions of risk’ can perhaps be assessed as ‘difficult’ based on the data generated in this study. In fact, with the exception of ‘under 10 living environment’ (zero statistically significant relationships in any cohort), all the demographic variables were found to significantly impact on the results from participants within individual cohorts; but only three out of nine variables were observed to be statistically significant in two cohorts. This was always the UK cohort plus one of the African cohorts (Table 7.2); a fact which underlines exactly how different the two African cohorts were in their survey responses and their perception and framing of fire. The fact is that many demographic aspects of both the NBA and Batwa cohorts were not ‘well-populated’ and thus did not appear to allow for significance to be identified (not enough people grouped within certain demographic boundaries - e.g. no Batwa had low breadth of fire-use and very few NBA had smoked). Probably for the same reason other statistical tests (e.g. Hierarchical Cluster Analysis and Logistical Regression) were also not able to illuminate significant relationships. These statistical tests were extensively applied to the data during this study; however analyses are not presented owing to a lack of useful results.

Table 7.2 does not however show the full picture of how clear some relationships are. For example, the four gender-related statistically significant relationships from the UK cohort all had males giving a more positive framing of fire than females. In the same way in all four of the statistically significant relationships from the UK cohort related to being burnt, those who had been burnt framed fire more positively. In 4/4 cases where significance was identified in the NBA cohort related to living environments rural inhabitants viewed fire more positively. As has been previously mentioned, where smoking status was identified as significant for the Batwa current smokers viewed fire most positively. In every instance where fire-use experience was identified as significant those with broader experience viewed fire most positively. Due to the fact that age-related results were sorted into six groups, and not two or three (as for most of the other variables), relationships were observed to be more complex; in general the oldest groups viewed fire most negatively where significance was identified, but often the results from one age group (frequently 18-24s) did not follow the general pattern.

Other statistically observed trends were not so clear. For example, survey results show that ‘parenthood’ produced opposing trends within different cohorts; in the UK cohort being a parent was in all cases significantly associated with negative feelings about fire (2/2) whereas in the NBA cohort being a parent was in all cases significantly associated with positive feelings about fire (3/3) (Table 7.2).

Again it is worth stressing that unfortunately, with the exception of the breadth of fire-use experience, clear trends were not observed cross-culturally; but it is proposed here that enough evidence was garnered to be able to make informed PLOF inferences. This evidence includes the cross-culturally visible ‘usefulness’ of fire that stands out much more clearly within the results than the postulated (prior to data collection) ‘attractiveness of fire’. This insight is here viewed as really important and is one of the key results focused upon in the discussion and conclusion sections of this dissertation.

The Attractingrepelling word-pair data anomaly

While data anomalies are not necessarily negative (it is clearly understood that anomalies can lead research onto interesting trajectories), the responses of Batwa respondents results related to the attractingrepelling word-pair seem odd and more than a little perplexing. When it became evident that of the three cohorts the Batwa had the most negative response to the attractingrepelling word-pair the first thought was that a translation error had occurred. However all translations (Appendix D) were cross-checked and agreed upon by four tri-lingual (Rutwa, English and Ruchiga) native Rutwa speakers prior to commencing data collection, thus reducing (but perhaps not entirely eliminating) this possibility. Thorough translations would not necessarily eliminate the chance of an error having occurred as a 100% direct translation of the word may not actually exist; after all English has a much broader vocabulary than Rutwa and it is well understood that words do not always translate directly between languages. Additionally, it may be that in this instance the 'strength' of the emotion conjured by the Rutwa translation of 'repelling' may be much greater than that conjured by the Rutwa translation of 'attracting'. The data does show (Table 7.1) that a large Standard Deviation was present in the Batwa data, but not abnormally so (the Standard Deviation was 0.01 smaller than the largest Batwa Standard Deviation). While Batwa results do *appear* to be anomalous (given other identified trends) perhaps it should not be classified as such so quickly as it may in fact be showing the genuine Batwa response to this word-pair.

FAF and cognitive evolution

It was earlier suggested that the implications of the FAF pathway links well with other key constructs of hominin niches such as social and behavioural changes (e.g. increased range and group sizes). FAF envisages that as *Homo* emerged and developed with its unique cognitive capabilities and neurological architecture, culture and landscapes of fear would intertwine ‘feeding back’ or ‘ratcheting’ each other thus influencing the direction of the development of behaviour, lifestyles and culture. So far the benefits of FAFs’ proposed affordances of the Wildfire Package have been somewhat viewed in isolation. However, it is proposed here, exclusive access to key resources (through tool use - including fire) could have stimulated increased rates of cultural evolution in ancient hominins. It is proposed here (and previously by Burton 2009) that Mode One fire-use might have been integral within complex feedback relationships that accelerated the overall rate of cultural evolution; at the same time stabilising positive attitudes to, and framing of, fire within hominin cognition.

The behavioural plasticity surrounding the onset, cultural flourishing or broadening of tool use seen in the Late Pliocene (typified by Lomekwian lithics) may have strengthened the desirability of the ‘usefulness’ of an object or natural phenomena. As tool use became more and more integral to hominin strategies and behaviour then this would also have been incorporated into hominin biology and psychology. It is here inferred that an increased reliance/dependence on tools coupled with a broadening of the awareness of different materials and landscape affordances would have brought the concept of something being potentially ‘useful’ to the ‘cognitive forefront’. Under these conditions examining and testing an object’s usefulness could expect to be an especially interesting, desirable and stimulating task underlain by neuroarchitectural substrates; behavioural plasticity itself can be viewed as being an adaptive selective force with substantial potential pay-offs. Perhaps the ‘new’ (or ‘newly strengthening’) realisation by ancient hominins that certain Wildfire Package affordances are useful (and potentially very useful) was evolutionarily important and is thus preserved within the cognition of *Homo*; now identified in this study’s cross-cultural survey.

Much previous work has been done on the evolution of hominin cognition, not least the work done by Dunbar, Gowlett, Gamble and colleagues on 'Social Brain' theories (e.g. Dunbar 2009, Gowlett et al. 2012, Dunbar et al. 2014, Gamble et al. 2014). FAF fits well with 'Social Brain' theories and does not appear contrary to any major aspect of them. Indeed FAF can be used to support wider aspects of Social Brain theories such as the evolution of larger cooperative social networks and increased range sizes. One specific way that FAF links in with Social Brain theories is through the recognition that efforts to lower predation risk represent the most likely explanation for the evolution of large community size among hominins (Majolo et al. 2008, Shultz et al. 2012, Josephs et al. 2016). It is plausible that selection pressures that favoured large cooperative social networks and niche construction, such as those generated by FAF, protected ancient humans from a diverse array of threats allowing the evolution of important behaviours (Mobbs et al. 2015).

Data collected in this study shows clearly that, among the modern human cohorts sampled, the more positively fire is viewed was correlated to the more interactions with fire a respondent had. This could be simply ascribed to being more cognisant of the positive aspects of fire (e.g. fire is useful, warming, a gift) but it is argued here that this does not fully explain why this would be so as a broader experience of fire would also provide ample opportunity to experience the negative aspects of fire as well (e.g. fire is scary, risky, a threat) as evidenced by the fact that nearly 80% of both the Batwa and the NBA cohorts responded that they had previously been burnt by fire (Table 6.45). It is proposed here that what this trend shows is a positive feedback in action.

(1) Personal experience of fire → (2) experiences both the benefits and risks of fire-use → (3) benefits perceived as outweighing risks → (4) benefit provides a pay-off of some sort (potentially of adaptive-selective significance) → (5) desire for more experience of fire

If this positive feedback trend is modelled into the cognition of Late Pliocene hominins then it can be easily envisaged how the strengthening of hominin fire-interactions could occur. However in this scenario a simple equation (‘the benefits of associating with the Wildfire Package’ minus ‘the risks of associating with the Wildfire Package’) would be substituted for stage (3) above. This feedback has to be contextualised into a period of heightened behavioural plasticity and evolving palaeoenvironments, which would have required significant hominin niche adaptations. This feedback loop may require the ability to collate and bridge information from numerous experiences and then form new higher-order representations, which modern humans are known to possess (Mercier and Sperber 2011, Mobbs et al. 2015).

While no evidence forwarded has yet proven that the earliest members of *Homo* possessed these abilities, let alone antecedents of *Homo,* relying on the archaeological record for proof of cognitive abilities or intelligence appears out-dated. For example, the presence of Lomekwian material has surely ended the debate as to whether Australopiths could make stone tools (a debate that may be reignited if evidence of *Homo* is eventually identified that predates 3.3Ma). Palaeobiological assessments of cognitive abilities in fossil hominins should not over rely on relative brain size or cranial capacities (Alba 2010); observations and research on extant great apes can also greatly help to infer the cognitive capacities of ancient hominin taxa (Pruetz and LaDuke 2010, Shultz et al. 2012).

Within an ancient hominin community it would not be expected for all members to have the same needs and therefore would be subject to different adaptive selective pressures that may not be uniform within the group. Perhaps specific demographic and age groups within a hominin community would be able to benefit more than others from Wildfire Package affordances. Following lines of reasoning laid out in both the Optimal Fire Following and

FAF hypotheses a strong case could be made to talk at length about specific and general benefits to foragers. However somewhat unexpectedly a clear FAF pathway started to emerge during fieldwork in Uganda; it clarified itself during subsequent data analysis and reviews of relevant literature. This FAF pathway pertains to the specific benefits obtainable by 'caregivers' (here taken as 'normally mothers' but not exclusively so – the Plio-Pleistocene role played by fathers, other kin and alloparents is another 'known unknown') infants and juveniles from exploitation of Wildfire Package affordances. This pathway highlights one way that FAF can easily spread and stabilise within a population.

This idea came out of the survey and as such is not tested in the metrical data. To include this topic here may appear a surprising choice as under-18s were not surveyed in fieldwork conducted in this study. However sufficient data was created pertaining to childhood living environments and whether respondents were parents or not to allow this topic to be approached. I believe it is important to really think this through here; not least because of the implications it has on future research directions (see Chapter 8). It is important to explain to readers that a 'great banner' is not being unfurled here which is mostly unsubstantiated by data generated in this study, but instead a potential 'pathway' is being discussed that highlights both the flexibility and the potential impact of the FAF hypothesis on a specific aspect of hominin paleoecology and related evolutionary trajectories. Other aspects of the wider implications of FAF could also be highlighted here in greater detail (e.g. honey acquisition), but it was decided to leave this topic to proposed later publications.

A specific FAF pathway – nurseries, caregivers and dependents

This FAF pathway proposes that pregnant females, mothers, caregivers and dependents are theoretically in an excellent position to benefit from the significant adaptive selective pay-offs hypothesised to be available through exploitation of Wildfire Package affordances; some of which may significantly help provide beneficial locations for nurseries. After carefully and fully laying out the case for this idea the question will be addressed of whether it is supported by survey data. While children weren't directly studied in the field survey[16] (except through chance observations), by mobilising this group it helps to explain how the uptake of hominin fire-use spread and stabilised within populations. As a parent of a young baby I have recently become very aware that perceptions of risk change with pregnancy and parenthood; it was very surprising to see no evidence if this in Batwa data or their behaviour. It was most surprising to see very young (but already independently mobile) Batwa infants being left alone in very close proximity to unguarded fires and precariously balanced saucepans full of food such as boiling potatoes.

One potential impact of Western low rates of childbirth would be heightened risk aversion as so much is invested in each child. It should be acknowledged that 'Western thinking' may heavily impact on how paleoanthropological researchers perceive the framing of hunter-gatherer risk factors, and also how the behaviour, actions and choices of ancient hominins are viewed. This is not to say that the Batwa (or ancient hominins) perceive or respond to risk to their offspring in ways that do not acknowledge the potential costs of injury and/or mortality. The investment made in each child cannot go unnoticed; however it did not appear to visibly

[16] due to ethical constraints imposed by the Ugandan National Council for Science and Technology and the strict requirements of the University of Liverpool for researching with minors (which would necessitate significantly increased resources and paperwork) the perceptions of fire of under-18's were not collected from any cohort

significantly impact Batwa framing of fire in this study (through personal observations or within analysed survey data).

Surprisingly only sparse literature exists pertaining to research conducted into the psychology of children and adolescents around fire; what there is identifies that children and adolescents appear to be particularly interested in fire (Murray et al. 2015 *passim*). Additionally, very little palaeoanthropological research has looked at specific issues by gender and age (one notable exception is the work done on the energetics of female *Homo erectus* by Aiello and Key 2002) and even less on children; perhaps this is another example of too many ‘known unknowns’ deterring potential researchers?

It is not only investments in vigilance while foraging (as predicted by conventional LOF theory) that are costly but also investments in vigilance while feeding youngsters and supervising playing and learning time. FAF proposes that being able to safely reduce these would have generated significant adaptive-selective pay-offs. A case can be constructed that the increased stress of terrestrial living and proposed increased group size would have placed strategies that reduced risk, and thus stress (risk = stress), under selection of maximum intensity. As mentioned throughout this thesis any use of an environmental factor that enables reductions to investments in vigilance or other risk effects without increasing risks can be highly beneficial, and any behaviour change that increases reproductive rate, survivorship or both will be under selection of maximum intensity (as per Lovejoy 1981). It is well recognised that hominin parental investments are significant and any mortality extremely costly (Hahn-Holbrook et al. 2011, Psouni et al. 2012). This area of hominin life has important implications for hominin development and evolution as the daily energy expenditure by female *Homo erectus* was calculated by Steudel-Numbers (2006) to have been

> 80% greater than female australopithecines suggesting significant change had occurred; extra energy was particularly needed during pregnancy and lactation (Aiello and Key 2002).

Highlighted in this FAF pathway is the potential role played by juvenile curiosity, behavioural plasticity, the unique nature of hominin learning systems and the fact that significant ontogenetic changes can result in powerful domain-specific adaptations (Sherwood et al. 2008). The placing of juveniles and infants within the suite of affordances offered by the Wildfire Package would provide ample opportunity for a broad range of innovative fire-use strategies and behavioural adaptations to emerge, spread and stabilise. Hominin infants are motorically altricial (Oudeyer and Smith 2016) and have a high-level of dependence on caretakers (Vasey and Walker 2001); they can only observe or physically interact with objects and events in the environment that their caretakers set for them (Oudeyer and Smith 2016).

Wildfire Package affordances can provide a rich set of social and environmental stimuli to the developing infant while the brain's connections are still highly malleable. Early-life exposure would help firmly cement hominin fire-use behaviour into hominin toolkits and behavioural repertoires very quickly. A long period of learning, which requires and promotes longevity (linked with extended brain growth, which also requires fuelling; which can be provided by high quality Wildfire Package resources), is recognised as a higher primate strategy to depress environmentally induced mortality (Lovejoy 1981). It is proposed here that the influences of aspects of Wildfire Package affordances on the behaviour of children (which will then be carried forward into adulthood) are likely to have been evolutionarily important.

An extended juvenile period would allow a protracted learning period during which new behavioural adaptations would have the opportunity to develop (Dunbar et al. 2014 *passim*) that if successful could then become adopted by other members of the group including later offspring; perhaps eventually becoming regional traditions and then finally, if sufficient adaptive selective pay-offs accrued, integral parts of a species' niche. Therefore this FAF pathway can be seen to result in a combination of significant fitness benefits to supervisors (particularly in resource stressed times when harvesting rates would have been diminished) and a suite of very important play/learning experiences for infants and juveniles that could have led (in a non-teleological way) to the stabilisation of Mode 1 hominin fire relationships.

Homo has been recognised as unique among primates in the amount of parental care required for offspring to reach reproductive age (Lovejoy 1981, Key 1998, Aiello and Key 2002, Hahn-Holbrook et al. 2011); this must have been subject to significant adaptive selective pressures. Compared to other primates, human offspring are highly vulnerable and heavily dependent on kin for many years (Hahn-Holbrook et al. 2011). For the first year postnatal brain growth in humans continues at foetal rates, whereas in other primates brain growth rates decrease shortly after birth (Leigh 2004). Human babies absorb so much information in this first year that directly impacts brain development (Sherwood et al. 2008). Early members of *Homo* and their antecedents must have successfully met the time and energy budgets relating to provisioning of and investing sufficient social time with offspring (Lovejoy 1981, Key 1998, Aiello and Key 2002)*;* this statement is proven by the success of *Homo*. How this was done is open to conjecture but one way of helping to meet these budgets would be to make adaptations to vigilance and anti-predation strategies. This proposal is here fleshed out to ascertain if there is any credibility in this idea.

To be clear, the scenario that is proposed here does not specifically state that the initial uptake of hominin fire-use was driven by female hominins; it merely identifies how Wildfire Package affordances might be particularly beneficial to individuals looking after babies and juveniles while at the same time highlighting the effects of Wildfire Package affordances on the learning and cognition of young hominins. By placing the curiosity, play and learning of young ancient hominins within the affordances of the Wildfire Package it provides a clear pathway for the positive framing of fire to develop, spread and stabilise. This is not instead of adaptive selective pay-offs being generated; this is in addition to plausible pay-offs being generated from the intelligent exploitation of physical and mental landscapes. Sherwood et al. (2008; P440) highlight the fact that the onset of joint attention in human infants occurs within the first year of life, "*providing the opportunity for intensive social facilitation of learning to influence synapse establishment during this period*". The 'palaeolandscapes of fear' (PLOFs) created when young would heavily impact on the nature of adult PLOFs and would steer future adult behaviour; perhaps especially when it came to choosing the landscapes to inhabit with ones' own offspring.

Amongst the many changes to hominin behaviour identified as occurring at or around the emergence of *Homo,* a significant increase in parental investment is inferred (Key 1998, Panter-Brick 2002, Pontzer 2012, Anton et al. 2014); therefore safe foraging areas and playgrounds, with low risk of predation, would have been required. More open areas created by the presence of wildfire on grassland/bushland environments would provide safer places for Plio-Pleistocene hominin infants and juveniles to play and be looked after (creating proposed significant LOF benefits): i) if ambush was the major predation risk; and ii) if once a predator was identified strategies were available to cope with threats posed. If these two assumptions were met (more 'known unknowns) an open environment with a clear field of view would have reduced the stress levels of hominins supervising adolescents or juveniles enabling increased attention for tasks such as social time, feeding or weaning; it may even have provided the opportunity for supervisors to multi-task, e.g. forage at the same time as supervising. It has previously been observed that to protect juveniles secure places that were relatively free from large carnivore competition (Rolland 2004) and conspecific threats were needed (Boyer and Bergstrom 2011); certain locations (e.g. kill or butchering sites) might not be safe enough, especially at night (Rolland 2004).

Reduced investments in vigilance would allow successfully increased investments in gestation, breastfeeding and childcare only if they don't reduce a mother's ability to survive. As pregnant females are at greater risk of attack by predators or conspecifics due to hampered mobility it would be expected that they would preferentially choose environments that are safer (Hahn-Holbrook et al. 2011); however this strategy must be balanced by the capacity to effectively balance the energy card. During evolution of the genus *Homo*, mothers must have begun acquiring foods of higher nutritional value (Vasey and Walker 2001). Acknowledging that small (beneficial) changes in foraging behaviour can have significant evolutionary consequences (as per Foley and Lee 1991), Wildfire Package affordance exploitation (specifically including reduced vigilance investments), could enable these disparate goals to have been met. This is not to say that it would necessarily have been done deliberately or teleologically; it is just as plausible that reductions in vigilance and anti-predation investments (including risk effects) allowed other budgets to be increased rather than reductions in vigilance and anti-predation strategies were made to meet other budgets.

Pre- and postpartum modern human parents reflect the nature of ancestral challenges by focusing on strategies aimed at averting threats of disease, accidents and stranger violence (Hahn-Holbrook et al. 2011, Panter-Brick 2002); as these problems appear highly adaptive ancient hominins can be assumed to have had similar preoccupations. Modern human children go through a long maturation period with major changes in potential dangers and reactions (Boyer and Bergstrom 2011); their fears seem to be much more about potential than actual threats, thus suggesting past evolutionary threats (Boyer and Bergstrom 2011).

Humans have developed a unique postnatal ontogeny that includes especially rapid brain growth and synaptogenesis in the first twelve months (Sherwood et al. 2008). It can be surmised that much of the way that modern humans frame their worlds derives from what happens when they are young, and potentially even before they are born (Kisilevsky et al. 2004); in this study this feature is expanded to Plio-Pleistocene hominins. During their extended period of dependency, human offspring need help to avoid a number of deadly hazards, including disease, accidents and hostile humans (Leckman et al. 1999, Hahn-Holbrook et al. 2011). For ancient hominins, all of these are potentially mitigable or reducable through Wildfire Package affordance exploitation.

To summarise this section a number of assumptions about Late Pliocene hominin behaviour are proposed here that combined would aid the proposed FAF pathway regarding the importance of relationships between Wildfire Package affordances and mothers, infants, juveniles and caregivers.

i) Gender-based divisions of labour may have been prevalent; female *Homo* antecedents and early members of *Homo* may have had different foraging priorities (as evidenced in hunter-gatherer and primate communities [Sherwood et al. 2008]), preferring strategies with guaranteed returns rather than potentially more risky strategies that may have been more attractive to males with different end-goals.

ii) The chance of ambush predation is reduced on a wildfire burnt environment due to a clearer, more open, field of view with fewer opportunities for predators to conceal.

iii) Social members of the large carnivore guild (e.g. lions) prefer not to inhabit or hunt in wildfire burnt environments (Eby et al. 2013).

iv) Hominins would greatly benefit from increased social time with their babies and juveniles in a relaxed risk and stress reduced environment (the fact that lactation attenuates stress [Hahn-Holbrook et al. 2011], possibly due to the comfort of knowing that the infant is safe and has food, shows the evolutionary importance of stress reduction to mothers).

Modelling in this area may also cast important insights on the unresolved issue of how maternal energy and hominin brain size evolution relate; the evolution of large brains must be energetically and developmentally accommodated (Barton 2006), which Foley and Lee (1991) suggested would require increased energetic costs of approximately 10%.

Archaeologically visible trends

FAF proposes that Wildfire Package affordance exploitation can provide coherent opportunities for adaptive selective pay-offs to be generated that would result in archaeologically observed hominin trends. These trends include: early weaning, gender-based social partitioning, and delayed infant maturation; these are now briefly outlined.

Many life history characteristics show modifications in hominins relative to other primates; skeletal, dental, and sexual maturation are delayed while juvenile periods and overall longevity is elongated (Lovejoy 1981, Hahn-Holbrook et al. 2011, Shultz et al. 2012 *Passim*) which are all suggestive of decreased risk pressure (e.g. from predators or conspecifics), which in turn is suggestive of successful new risk reduction strategies having evolved (Lovejoy 1981). Contrary to this idea Tobias (2006) identified increased mortality in early members of *Homo* relative to late australopithecines which could have resulted from increased predation pressures (particularly on infants and juveniles) which would have provided strong selective pressure to increase birth rates by reducing inter-birth intervals, thus requiring earlier weaning (Aiello and Key 2002, Aiello and Wells 2002, Dunbar et al. 2014); earlier maturation was evidently not pursued in response to the thinking of Tobias (2006) as this would have been counter to encephalisation trends. Whichever perspective on ancient hominin risk levels is closer to reality, as infant dependency periods elongated then behavioural changes involving increased parental care and better quality provisioning would have been required (as per Shultz and Dunbar 2010 and Shultz et al. 2012).

Primates require more food energy during lactation than during any other reproductive stage including gestation due to less direct and less efficient energy and nutrient transfers (suckling infants are at a higher trophic level than mothers and therefore significant proportions of the energy in milk is lost) and greater thermoregulatory stress and activity levels in infants relative to foetuses (Vasey and Walker 2001 *Passim*); therefore early weaning can provide clear adaptive selective pay-offs. Early weaning has implications for offspring development and inter-birth intervals which can significantly impact female reproductive rates influencing population dynamics and biological fitness levels (Psouni et al. 2012 *Passim*).

Early weaning requires high quality weaning foods to substitute for milk, which exploitation of Wildfire Package affordances can provide. It has been previously noted that relatively small amounts of a high-quality resource (predicted to be accessible through exploitation of Wildfire Package affordances) could make a significant difference to when weaning can occur, as well as enhancing lactative capabilities (Foley and Lee 1991). Early weaning would enable a female to have multiple immature-dependent young. Dunbar et al. (2014: P82) suggest that '*having multiple immature-dependent young will cause knock-on consequences for social group structure, foraging behaviour and range use, and could drive the evolution of cooperative breeding, nurseries and central place foraging'*; the FAF pathway of Wildfire Package exploitation fits neatly within this nexus of adaptations.

Many primates display significant sex differences in foraging (Lovejoy 1981 *Passim*). Lovejoy (1981) identified that for ancient hominins increased separation of males from females and offspring is advantageous as the feeding rate was limited by search time rather than handling time. As has been shown in this thesis (Chapters 2, 3 and 4) some Wildfire Package affordances enable both reduced search and handling times (e.g. burning away of undergrowth enabling cryptic animals to more easily be found, and small mammal mortality from smoke or flames [Photos C and E]). A key element suggested to have facilitated changes in parental investment was efficient gender-based division of labour in acquiring food (Kaplan et al. 2000, Kaplan and Gangestad 2005, Fletcher et al. 2015). Even when controlling for body weight larger brain size in primates is associated with receiving help from non-mothers when rearing offspring (Isler and van Schaik, 2012).

Gender differences in parental precaution exist due to factors including sexually selective forces and differing levels of parental investment (as with most broad statements a wide spectrum exists which includes outliers). Due to parental certainty the energetic costs of pregnancy and breastfeeding, women invest more heavily than males in each offspring they produce; including investments in precautionary behaviours (Hahn-Holbrook et al. 2011). As hominin precautionary psychology is designed to protect offspring (Hahn-Holbrook et al. 2011) strategies that result in safer environments will be positively selected for; maternal behaviour is under strong selection pressure to increase offspring's survival chances (Otali and Gilchrist 2006). A mother will try to balance the costs and benefits of different strategies and adjust her behaviour to maximise the biological fitness of herself and her offspring (Otali and Gilchrist 2006).

The idea of gender based social partitioning around childcare and nurseries fits with the acknowledgement that Plio-Pleistocene hominin group size increased due to trends of:

increasing terrestriality, cognitive complexity, and dietary quality (including possibly increased carnivory), thus requiring larger ranges. The segregation of individuals by sex and age for specific social activities (e.g. foraging) is a great ape trait, especially humans and chimpanzees (Sherwood et al. 2008). Due to different foraging priorities, after a wildfire event (which dependent on the specific nature of the individual event may, or may not have created significant immediate foraging opportunities), male hominins may preferentially forage away from the wildfire burnt environment as returns for some (e.g. meat) resources may be higher in non-burnt landscapes. This is irrespective of whether big-game hunting or power scavenging was the preferred foraging tactic as it is more difficult to successfully ambush prey in a burnt open environment (Eby et al. 2013). This FAF pathway connects a reduction of conspecific threats (a problem in the hominin lineage [Boyer and Bergstrom 2011, Hahn-Holbrook et al. 2011]) with exploitation of Wildfire Package affordances; thus providing adaptive selective pay-offs (that are dependent on factors such as the nature of ancient hominin social structures and the strength of conspecific risks).

If non-caregivers avoided competition by foraging (hunting, scavenging or gathering) elsewhere, due to less direct competition this would allow for greater gestational and lactational loads even if they didn't bring food home for caregivers; which they might have to have done as delayed maturation requires huge investments from more than one person (Fletcher et al. 2015). Due to a proposed higher quality of diet (and therefore increased 'choosiness') separation during foraging can be suggested to have been under strong positive selective pressure. This can also be deduced as reducing conspecific threats (Lovejoy 1981); primate caregivers with dependent offspring are especially sensitive to the dangers of conspecific threat (Otali and Gilchrist 2006).

Benefits to pregnant females and caregivers

The potential benefits to caregivers from the FAF pathway are numerous and can be thought of in terms of: a reduced need for mobility as Wildfire Package affordances can enable calorific and nutrient budgets to be met; and reduced stress levels due to clearer fields of view and possibly reduced conspecific threats. Both of these would have enabled ancient hominins to produce the archaeologically observed trends previously discussed.

Parenthood and childcare is stressful in part because precautionary systems naturally generate worry and heightened anxiety levels over potential future harm coming to offspring (Hahn-Holbrook et al. 2011). Female reproductive hormones prime parental affiliation to incentivise offspring protection, focus parental attention to potential threats, and thus facilitate defence against potentially dangerous conspecifics and predators (Hahn-Holbrook et al. 2011). While interactions with offspring generate reward responses which buffer otherwise deleterious levels of heightened anxiety (Hahn-Holbrook et al. 2011) other methods of reducing background stress levels (e.g. intelligent landscape use) could also have been adaptively significant. The mosaic environments inferred by researchers as the ancient hominin habitat(s) of choice shows that choices and trade-offs were constantly made between differing competing needs. As material culture increased in complexity these decisions and trade-offs can be deduced as becoming more complex and therefore of greater significance to evolutionary trajectories; as evinced by Late Pliocene hominin speciation events.

Some monkeys (e.g. *Cebus capucinus*) deploy a risk reduction strategy that reduces time spent foraging and overall energy intake during pregnancy (decreased overall energy expenditure and more time spent stationary in safer areas offsetting reduced calorie consumption) (Rose 1994). However this kind of strategy may not have been available to ancient hominins due to the metabolic demands of relatively large brains which exert strong constraints on brain size (Barton 2006); obviously large brains cannot be developed or maintained unless required metabolic demands are met (Shultz et al. 2012). Another very important point to consider for pregnant and lactating hominins is access to sufficient minerals. In modern populations the relatively higher requirement for mineral intake during pregnancy has been repeatedly associated with a desire for the direct consumption of minerals (Allen 2005). When extrapolating this association back to ancient hominins, due to the transformational nature of wildfire the subsequent proliferation of 'minerals on the landscape' (ash) can be viewed as a valuable resource to exploit with significant benefits.

The need to forage requires mothers and infants to remain mobile (Lovejoy 1981) which has fitness costs as mother-infant mobility is a significant cause of mortality and places an important restriction on primate birth spacing (Lovejoy 1981). The high costs involved in carrying a primate infant (e.g. increased energy expenditure and reduced speeds) limit a caregiver's mobility (Altmann and Samuels 1992). Additionally caregiver's with dependents that don't require carrying may be limited by the mobility capabilities of dependents (Otali and Gilchrist 2006). Therefore lowered mobility of caregivers and dependents would theoretically reduce exposure to predators and allow intensification of parenting behaviour thus elevating survivorship (Lovejoy 1981). In a number of hunter-gatherer societies, reduced mobility in association with reproduction has been found to result in decreased foraging intensity and increased reliance on provisioning from mates or kin (Quinlan and Quinlan, 2008). FAF proposes that exploitation of Wildfire Package affordances related to both provisioning and safety could reduce the need for ancient hominin caregiver and dependent mobility without necessarily reducing abilities to balance energy budgets; thus providing significant adaptive selective pay-offs.

Ethological support for this position

Much work has been done on chimpanzee maternal strategies that can yield useful models for researchers to work with (as long as it is implicit that chimpanzees cannot serve as direct analogues for extinct ancient hominins [Stiner 2002]). A number of key behavioural trends of relevance to this FAF pathway have been identified from observations on wild chimpanzees.

i) *Pan* maternal vigilance is higher when a dependent infant is separated from its mother than when the offspring was in contact (Kutsukake 2006).

This suggests that if the 'background rate of vigilance' is (relatively) low, as FAF predicts when a hominin mother resides in an 'open, risk-reduced environment' such as a wildfire burnt environment, more scope would then exist to increase vigilance investments if required. Reduced background levels of vigilance investments would also allow a trend of slower infant maturation as high levels of parental investment can be maintained for longer; the daily costs to a mother of having a juvenile would reduce. In addition as an infant has predicted reduced risks (from predators or conspecifics) less selective pressure exists to quickly pass on genes allowing slower maturation to stabilise within populations; this has attendant significant implications for brain-growth as prolonged life history phases have been shown to relate to the evolution of large brain size (Sherwood et al. 2008 *Passim*). An extended period of offspring dependency, combined with more slowly maturing neuronal pathways, also provides increased opportunities for 'learning in a social environment' to strongly shape the developing brain (Sherwood et al. 2008).

ii) Female *Pan* termite fishing occurs mostly when alone with offspring or maternal kin (Tennie et al. 2014)

Dangers to vulnerable infants exist within many large social groups (Wrangham and Peterson 1996, Otali and Gilchrist 2006); therefore both injury risk and psychological stress can significantly increase in the presence of conspecific males (Otali and Gilchrist 2006). The observation of Tennie et al. (2014) suggests that some foraging strategies require so much focus that in certain situations (e.g. when both risk levels and required levels of vigilance are high) that a strategy is viewed as unviable and not worth pursuing. Perhaps foraging within a wildfire burnt environment nursery with its reduced risks, including proposed reduced conspecific risks, would have shifted some strategies (e.g. entomophagic strategies such as termite fishing or digging for tubers) from unviable to viable opening up panoply of new dietary opportunities; these may have been especially important during periods of severe resource stress. The opening up, or improving the viability, of some foraging strategies could have important implications while pregnant, breastfeeding and/or weaning as it is particularly advantageous to ensure enough food is available at metabolically expensive periods of reproduction (Attwell et al. 2015). Here it is deemed plausible that exploitation of Wildfire Package affordances could have resulted in outcomes such as early weaning, larger neonates, shorter inter-birth intervals, higher quality weaning foods and safer nurseries all of which can have adaptive selective pay-offs and thus impact hominin biological fitness.

Hopefully a strong case has been made here that irrespective of whether conspecific threats or threats from predators constituted the main risks faced by ancient hominins a wildfire burnt environment would make a relatively safe place for a nursery with a range of potential significant adaptive pay-offs for those who chose to utilise them. This may have very important implications for how researchers view the earliest hominin fire interactions and the nature of the earliest adaptive selective pay-offs provided by hominin fire relationships.

Is this position supported by survey data?

Data generated in this study does clearly show how 'the more broad the range of benefits personally experienced by an individual the more positively they view fire' and the strong cross-cultural positive perception of fire as a tool. These were observed to be crucial in determining the modern human LOF and it is proposed here this was true in the PLOFs of all members of *Homo* and their immediate antecedents. It may be simply that as the breadth (or depth) of experience a hominin has with fire increases, the risks of associating with fire will also increase but at a slower rate than the benefits increase. As fire can be viewed as a very adaptable composite tool the more one experiments in novel ways with the Wildfire Package then the greater the payback (and adaptive selective pay-off) might be. The very broad nature of potential benefits linked to the range of Wildfire Package affordances provided within physical and mental landscapes shows how early-life exposure could provide greater access to opportunities. Environmental features become bound together within mental landscapes such that future encounters with a similar context or event are able to evoke memories or representations of their consequences (as per Mobbs et al 2015).

By combining: i) Fessler's (2006) 'five-featured' model of how fire-learning works (outlined in Chapter 4); ii) the results of data generated in this study; and, iii) the results of data generated in Murray et al. (2015), and then extrapolating this thinking to ancient hominin infants and juveniles, it is possible to conclude that not only would the more curious and explorative hominins have access to the most Wildfire Package affordances and benefits but they would also like and positively frame fire the most. It can be argued that this selection pressure would create a desire to interact with fire when it becomes available; which may have been either biologically or culturally mediated. It is proposed here that it would be initially culturally mediated but eventually, by the time *Homo* first successfully left Africa, it would be biologically fixed; otherwise the modeling breaks down when *Homo* leaves Africa potentially losing their close affinity with fire when inhabiting fire-free or fire-sparse environments. The biological fixing of a positive framing of fire within hominin neural architecture before *Homo's* out-of-Africa migrations would not require obligate fire behaviour but does provide a coherent pathway for future hominin fire interactions to be quickly reincorporated into hominin toolkits as and when fire became available.

While the survey results presented in this dissertation may have generated conflicting trends relating to parenthood and attitudes to fire the results do highlight the way that people's perceptions of aspects of the Wildfire Package can be affected by factors such as parenthood. Parenthood brings new responsibilities and risks (a positive correlation to framing fire positively was observed in the NBA cohort [fire was seen as more social, friendly and cleansing by respondents with children than without]; no correlation between parenthood and responses to word-pairs was observed in the Batwa; and a negative correlation to framing fire positively was observed in the UK cohort [fire was perceived as more dangerous and scary by people with children than without]). The only statistical significance identified directly pertaining to gender was observed in the UK cohort where males (in 4/11 word-pairs) were statistically more likely to frame fire positively than females (females viewed fire as more risky, violent, hazardous and fearsome than men - In none of these word-pairs was parenthood identified as also being a significant factor in how participants responded).

Following these results, (possible) gender based behavioural relics do not directly support this part of the FAF hypothesis; but this does not destroy this aspect of the FAF hypothesis argument. It may be that: i) adult males were equally able to benefit from some affordances of the Wildfire Package (perhaps those affordances related to a male propensity for greater risk-taking); ii) (as argued by Lovejoy 1981) adult males played important roles in ancient hominin childcare; or iii) that the statistical significance observed in the UK cohort was linked to more modern cultural trends.

Other parts of the dataset, such as the data generated from the variables parenthood, age and breadth of fire-use experience are also useful tools to examine this FAF pathway. As was mentioned previously whether a respondent had children or not produced different trends in different cohorts. It would appear wrong to use one trend to support the suggestion proposed here and then ignore the opposing trend. The fact that no significance was observed in the Batwa cohort relating to either gender or whether a respondent had children or not could mean a number of things including that: neither variable had any significant impact on how the Batwa create their attitudes to, or relationships with, fire; or, that this methodology was not able to identify the impact on Batwa fire-based LOFs of these demographic variables. Therefore the only way to support the idea that childcarers may have benefited from the tenets of FAF with data collected in this study is to use the clear cross-cultural trends within the 'breadth of fire-use experience' data.

As already seen data generated in this study shows that the broader a person's personal experience with fire then the more positively fire is framed in their personal LOF. Murray et al. (2015) came to a similar conclusion albeit they used very different methodologies; they concluded that in the two North American cohorts they sampled (which had significantly different levels of exposure to fire) people's affective associations with fire were overwhelmingly positive. Results from one study suggested that a higher frequency of exposure to fire in childhood (as well as greater proficiency with fire-use) is related to higher positivity toward fire in adulthood, and a higher likelihood of having used fire for entertainment purposes in adolescence. As in this study, the positive framing of fire observed was independent of any potential effects of negative experiences with fire. Murray et al

(2015: P212) concluded that '*this psychological proclivity for fire demands a comprehensive explanation'*. The FAF pathway presented here has attempted this but data generated in this study does not (conclusively or otherwise) prove the theoretical case made.

Chapter 8 - Conclusions and implications

With a deep evolutionary history and profound impacts on fitness, there is every reason to believe that fire has been a source of recurrent and substantial selective pressures shaping human behaviour and psychological architecture (Fessler 2006)

This study has examined current theories about early human fire-use and found that one of the limitations is that almost no study has been devoted to modern human attitudes to fire; perhaps its principal contribution is that it has attempted to remedy that position through systematic field studies. In addition this research has entailed an innovative exploration of early fire theories stimulated by apparent incongruencies between rational plausibility and existing explanations for the initial uptake of deliberate opportunistic hominin fire relationships. From the start it was highlighted that the study of the nature of the earliest initial interactions between hominins and fire could benefit from new ecological approaches.

An understanding of how and why hominins utilise their landscapes and environments is central to the study of hominin ecology and evolution (Willems and Hill 2009) as are the structures that underlie hominin decision-making processes. A wide body of literature shows that the desire to feel safe and minimise risks determines to a large degree the habitat use choices of primate communities (e.g. Cowlishaw 1997, Jaffe and Isbell 2009, Herzog et al. 2014). Additionally, specific to late Pliocene and early Pleistocene ancient hominins, strategies to mitigate stress are here proposed to have been potentially very strongly selected due to factors such as expanding group size and increasingly terrestrial niches (with potentially significantly greater interactions with large carnivores), both of which would have increased stress levels through a number of different pathways (Lovejoy 1981, Shultz et al. 2012, Gamble et al 2014).

While the use of fire as a way to physically deter predators is well documented it was felt that the impact of fire on the landscape, and the effects of this on the behaviour and choices of all trophic levels including prey and predators (which creates a broad range of exploitable opportunities) deserved much fuller study. From the start this study has been focused on approaching this topic from a new perspective with heuristic innovative thinking and methodologies, with the ultimate aim of helping to enable a more realistic and less anthropocentric paradigm of the onset of early hominin fire-use to emerge and stabilise.
All universal human traits will have an evolutionary history. The Fear and Flames Hypothesis (FAF) has been deliberately constructed as a pyrogenesis hypothesis; therefore a clear suggestion of this study is that fire has been so fundamental to the emergence and development of *Homo* that responses to fire are deeply imbedded within the cognition of modern humans. Through this reasoning comes the idea that fire is so fundamental that responses are deeply imbedded within human neural architecture. Therefore modern human framing and perception of fire will be guided by a combination of hard-wired and cultural stimuli. Aspects of this concept were cross-culturally tested in this study.

Research objectives:

The primary aims of this research were threefold. Firstly to quantify exactly how modern populations' think about and frame fire with relation to risk; something that was identified as both lacking from the extant body of knowledge and as potentially extremely useful to researchers. The second main aim of this PhD study was to generate a simple coherent non-teleological hypothesis that would describe and explain the earliest uptake of opportunistic hominin Mode 1 fire. The third principal aim of this research has been to generate high quality data that can test inferences made about the role of fire as a strong selective force during the emergence of *Homo*. In addition to these three stated aims another clearly identified personal goal was to design, construct and implement a robust, high quality, coherent research programme that developed, tested and showed competence in a set of generic skills (e.g. analysis/sampling/survey design), and enabled the development of a level of expertise within a specific subject area.

Contributions to knowledge

This research project has been conducted with the view that the past cannot be investigated by a single record; researchers must seek to combine several lines of evidence. This study has produced one major new line of evidence that it is hoped will be of use to other researchers. However it is believed that the research has made three unique and needed contributions to the study of the origins of hominin fire-use.

i) The principal contribution is the design and successful deployment of the first systematic study into the attitudes and framing of fire using cohorts recruited from different societies including a recent hunter-gatherer community; results have been analysed in depth and trends and correlates identified.

ii) The second proposed original contribution to the study of the origins of hominin fire-use is the 'Wildfire Package' concept (wildfire, wildfire created resources and wildfire burnt environments); this can encourage a new way of thinking about early human fire use.

iii) The third contribution to the study of the origins of hominin fire-use is the setting forward of the Fear and Flames hypothesis (FAF); a new hypothesis concerning early hominin fire-use that focuses on strategies to mitigate fear and risk factors and reduce the costs of vigilance investments.

These three contributions are now briefly summarised.

This study broadened the extant body of academic knowledge by identifying, quantifying and comparing characteristics of modern relationships with fire from three different communities and tested to see if these are affected by variables including: age, gender, whether participants have children and whether respondents have had previous negative experiences with fire. Currently available archaeological evidence does not allow the direct evaluation of the landscapes of fear (LOFs) of ancient hominins (termed palaeolandscapes of fear, or PLOFs) so an innovative questionnaire based survey methodology was designed and deployed to identify the nature of modern fire-related LOFs by identifying current attitudes to, and 'framing' of, fire. In this study it was proposed that some trace of the impact of fire on the ancient hominin PLOF could be visible in the cognition and psyche of extant populations, as postulated by the general tenets of evolutionary psychology.

It was hypothesised that ancestral conditions and relationships would be most evident in the LOF of hunter-gatherer communities as they maintain the lifeways that are most close to ancestral lifeways. To generate inferences about the earliest hominin relationships with fire the fire-related LOF of a hunter-gatherer community needed to be documented and studied to act as a 'very rough analogue' of ancient hominins; the methodology chosen was that this would be part of a cross-cultural comparison so that ancestral features and relationships could theoretically be better illuminated. This study never lost sight of the fact that studies of modern humans can be clouded by multiple confounding factors including cultural differences and attitudes towards the data collection methodology itself.

A key part of this methodology was the creation of eleven word-pairs all of which could be broadly classified as containing: i) a positive aspect or trait of fire, or a positive emotion that could be used to describe fire; and ii) a negative aspect or trait of fire, or a negative emotion that could be used to describe fire. The words picked were all chosen as they were specifically relatable to fire and could therefore feasibly all be ‘strongly selected’ for or against. Word-pairs were specifically designed not to be direct opposites of each other to aid the attempt to identify and quantify individual respondent’s personal attitudes to, and framing of, fire. A continuous scale was offered to respondents to find their own personal balance between the two conflicting words; this was then later numericised into scores of 1-120. Word-pairs were chosen rather than individual words so that the relative merits of the positive and negative impacts of fire could be measured. While placing a mark in the centre of the scale (a score of 60) gave an equal balance, providing word-pairs to compare made it much more difficult for respondents to simply agree with all proposed aspects of fire.

The second proposed original contribution to the study of the origins of hominin fire-use is the ‘Wildfire Package’ concept; an original perspective of fire that encourages a broader way of thinking about fire that is not anthropocentric in its approach. Humans possess the ability to collate and bridge information from numerous experiences and form new higher-order representations (Mobbs et al. 2015); FAF supposes that this acknowledgment is extendable to early members of *Homo* and their immediate antecedents. In this study many species have been cited as having adapted to take advantage of Wildfire Package affordances (e.g. Vervet monkeys and Topi). FAF by mobilising the Wildfire Package concept has highlighted a way that hominins would have built upon the very simple exploitation strategies of other (primate and non-primate) species, enhancing the complexity and in the process generating (proposed) significant adaptive selective forces and pay-offs. Even if FAF generates little support in the research community it is hoped that this non-anthropocentric perspective of the varied and diverse affordances of wildfire on the landscape can gain traction in the wider research community; this would be classed as a successful contribution to this field even if the term itself does not necessarily become common usage.

The third proposed contribution to the study of the origins of hominin fire-use is that a new hypothesis about early hominin fire-use has been constructed and laid out that takes into account fear and risk factors on the landscape; aspects of this hypothesis have been tested in my analysis. Palaeoanthropologically and archaeologically garnered information from hominin evolutionary past has been collated and reordered to create FAF; a hypothesis that explains past relationships and highlights the nature of specific adaptive selective forces and the pay-offs that can have been generated as well as contextualising and informing researchers about present attitudes and relationships with fire. FAF is in accord with the idea that environmental variability and risk factors impacted on cognitive evolution indirectly via changes they imposed on hominin social environments (as per Shultz et al. 2012).

FAF requires viewing fire as a useful tool (in the hand but particularly in the mind) that has environment altering and niche building capabilities (as per Attwell et al. 2015). FAF is focussed on the joint mental and physical benefits that can be gained from non-complex landscape level interactions between ancient hominins and Wildfire Package affordances. A main contribution of this thesis is to suggest that, in addition to those previously described within the literature, a further suite of adaptive-selective forces and pay-offs drove the initial uptake of anthropogenic fire-use; these forces were generatable by the preferential exploitation of Wildfire Package affordances that exist within hominin mental landscapes.

The proposed timing of FAF in the late Pliocene/early Pleistocene is a time of rapid change and adaptation in hominin toolkits denoting high behavioural plasticity (Potts and Faith 2015). However it should also be considered that ancient hominin evolution can be studied by general arguments that do not specifically need to be pinned to particular time points. The number of unique *Homo* morphological and behavioural traits provides enough context and need for many new adaptations. The acquisition of basic Wildfire Package exploitation strategies makes sense when considered as adaptive behaviours in the context of natural selection, which favours the evolution of domain-specific cognitive systems that handle recurrent fitness challenges (as per Mobbs et al. 2015). The emergence of *Homo*, a new genus, required entirely new niches that incorporated different social structures, diets, feeding strategies and body plan; therefore *Homo's* mental inter-specific, extra-specific and environmental relationships would also have been very different.

FAF does not propose one line of reasoning but specifically proposes a range of small benefits and strategies (potentially in the form of 'regional cultural traditions') that when amalgamated would have generated significant adaptive pay-offs. This appears the most appropriate way to model the benefits of Wildfire Package affordance exploitation given the ephemeral and varied nature and range of scale of wildfires and their broad spectrum of impacts on landscapes and environments. FAF proposes that mental affordances of the Wildfire Package would have complemented physical (e.g. foraging) affordances and in this study are proposed to create a package of adaptive-selective pay-offs that would stimulate the uptake and stabilisation of the earliest deliberate opportunistic hominin fire interactions. The benefits of reduced stress and reductions to required vigilance investments, which then allow more time to be spent on feeding or other social strategies, can act in combination with foraging benefits. The ability to effectively utilise the panoply of resources available within the Wildfire Package would have generated significant adaptive selective pay-offs for those hominins that chose this strategy. FAF pathways can lead to specific benefits including:
i) reduced levels of predation; ii) significantly increased social time; iii) significantly increased opportunities for parental investment; iv) significantly increased dietary quality;
v) significantly less stressful fearful lives; vi) numerous opportunities to experiment with new highly beneficial strategies (e.g. smoke-assisted honey-collecting).

FAF places the onset of hominin fire relationships prior to the appearance of *Homo* (by unnamed evolutionary antecedents) and specifically states that fire-use enabled Homo to emerge as a genus of very basic level fire-users. ***In this study it is not proposed*** that the pathway laid out in FAF created the initial opportunistic hominin fire relationship which then set off a strong ratchet effect, whereby the initial adoption of a close association with fire by an early hominin would isolate that lineage and lock it into a rapid series of adaptive changes that would drive the elaboration of existing anatomical, cognitive, social and technological capacities to better exploit the new niche; feeding back into each other and stabilising new behaviours and adaptations (both mental and physical) until the accumulation was so great that researchers recognise a new genus had emerged.

What is being proposed is a much more subtle suggestion that the pathway laid out in FAF created the initial opportunistic hominin fire relationship which was part of a nexus of behavioural plasticity and adaptability that along with other concomitant technological and behavioural traits developed as a response to increasing climatic variability and created such dramatic niche changes (partly constructed) that a new genus eventually emerged. *Homo*, the new genus, had very different environmental relationships and very different cognition (not only in terms of intelligence but in terms of environmental framing and trophic positioning) including a much altered PLOF. FAF views *Homo* as emerging with sufficiently enhanced mental and physical architecture that its ability to adapt, broaden or construct its niches meant that it had become highly eurytopic eventually facilitating intercontinental migration.

It should be clear that FAF is not proposed to be able to '*end the early fire debate'*. Many greater minds than mine have approached this subject over many years from diverse directions (e.g. Burton, Gowlett and Wrangham). However challenging well-established ideas with a fresh eye is often worthwhile and can bring new insights. What I believe has been necessary is to bring into the debate some of the tenets of FAF related to the benefits of effective and innovative risk management and stress reduction strategies, as well as intelligent use of physical and mental landscapes; many aspects of which seem to be stark in their absence from previous ideas. One important way that science progresses is through the formation and testing of hypotheses (Fisher 1925); Archaeology needs ideas that may not be entirely right but that open up new ways of thinking. This original research should be viewed as a step in investigating certain hominin traits around the framing and perception of fire. However none of the scenarios presented in this dissertation (e.g. related to the 'usefulness of fire', or 'nurseries, caregivers and dependents') can be fully substantiated at present.

A synthesis of the theoretical framework, results and conclusions

A review of the literature shows that an understanding of early human fire-use can be obtained from a number of sources. While in many areas of palaeoanthropology archaeological evidence has the potential to be the most direct way of accessing ancient behaviours (providing an adequate framework exists for interpretation), ancient fire-use has proved an exception to this (Attwell et al. 2015) due to the poor preservation potential of fire, the inability to differentiate Mode 1 fire-use from wildfire not utilised by hominins, and the acknowledgment that fire is very often missing from sites where researchers are certain it should be. To move away from 'what you see is what there was' ways of thinking innovative indirect methodologies are required to approach this topic. In this thesis a number of key points from a range of palaeoanthropological topics have been clearly laid out and coherently discussed using aspects of evolutionary psychology theory, and behavioural ecology theory, amongst other framings. These palaeoanthropological topics include:

i) Why the initial uptake of hominin fire is so important to a more complete understanding of the course of human evolution.

ii) Why existing early fire theories have failed to achieve widespread credence amongst researchers.

iii) The potential adaptive-selective importance of adaptations within hominin mental landscapes; in addition to those available within physical landscapes.

iv) The role of adaptability and infant/juvenile/adolescent curiosity on the spreading and stabilisation of hominin fire-use.

The results of research in these areas led to the construction of FAF which suggests that hominin evolutionary history will impact on the mental framing of fire by modern human populations; this was then tested for. To ensure survival a species needs to obtain sufficient nutrition, balance required social budgets, breed successfully and manage risks related to predation and injury (Gamble et al. 2014). To some degree or other FAF addresses all of these issues in a coherent manner as well as attempting to explain the initial onset of hominin fire-use which has been often identified as a very significant moment in hominin evolution (e.g. Darwin 1871). It might even be as significant as the initial use of lithic technology (another important hominin tool and method of niche construction); therefore having a coherent elegant model for the uptake of hominin fire-use is of paramount importance.

While previous studies, identified during a forensic literature search, have identified the contribution that altered giving-up densities and reduced investments in vigilance can have in improving the biological fitness of an organism or community (e.g. Brown 1999, Brown and Kotler 2004, Laundre et al. 2010) (either of which could be viewed as a robust biological driver for an ever closer relationship with fire if sufficient adaptive-selective pay-offs are generated). Prior to this study a PLOF analysis on either: i) wildfire specifically; or ii) ancient Plio-Pleistocene hominins had yet to be conducted. This has now been somewhat rectified by making inferences using survey data collected from modern humans.

Survey fieldwork within this study quantified and compared attitudes to fire from three culturally diverse modern communities of *Homo*; two cohorts were recruited in Uganda including a cohort made up entirely of ethnic Batwa (recent hunter-gatherers now mainly subsistence labourers) with the third cohort randomly recruited in the UK. This search for psychological behavioural relics within the cognition of modern humans as a way of empirically testing palaeoanthropological theories has been rewarded with the illumination of a number of key similarities, differences, trends and patterns. Data from the different cohorts was more different than could have been expected. Some key research findings are:

i) The Batwa have a much more positive framing of fire than the other two cohorts.

ii) The UK cohort framed fire more similarly to the NBA cohort than the Batwa.

iii) ‘Western-thinking consumerist’ Africans have significantly different framing of fire than subsistence labouring recent hunter-gatherers despite inhabiting the same region.

iv) The breadth of fire-use experience was closely correlated with a positive framing of fire.

v) The only trait given an overall positive framing by all three cohorts was that fire is more useful than hazardous and the only trait given an overall negative framing by all three cohorts was that fire is more destructive than cleansing.

That the Batwa have a very positive framing of fire that includes the heightened awareness of the usefulness of fire is very interesting. What is perhaps even more interesting is that despite the UK and NBA cohorts having more negative overall framing of fire the theme of fire's usefulness shines through in the data of all three cohorts; this was even the case when people had personally suffered adversely from fire. Both African cohorts can perhaps be expected to perceive fire as a tool as the data shows that individually they have used fire 'as a tool' in many diverse ways. The UK cohort less so (20% had used fire in three or less ways); based solely on personal experience would the UK be expected to think like this? Or did deeply imbedded inherited ways of thinking impact on their responses? In this study, along with the positive correlation between the positive framing of fire and the breadth of fire-use experience, the cross-cultural acknowledgment of fire's usefulness was a key finding that helps to make clear inferences about ancient hominins attitudes to, and framing of, fire.

If these two findings are ancient behavioural relics then they would help to explain how a positive attitude to fire would enable vigilance reductions (either less frequent scans or less time taken per scan due to the openness of the environment) to be achieved through the utilisation of clear fields of view. In addition if members of the Late Pliocene African large carnivore guild displayed the same broad behaviours as the current African large carnivore guild do around burnt environments then spending time within wildfire burnt environments would reduce the number of encounters with inter-specific threats with attendant reductions in decreased predation risk and decreased risk effects; creating significant adaptive selective pay-offs. This leads on to finally addressing the main research question posed in Chapter 4. Could adaptive selective pay-offs created by adaptations within ancient hominin landscapes of fear provide a robust driver for the initial uptake of hominin fire-use? Another way of phrasing this is simply: Can the FAF hypothesis be considered robust?

FAF was created knowing that it can never 'be proven' only refuted (as per Fisher 1925). In addition to philosophical (Popperian) reasons, in this case it is understood that it cannot be proven because researchers will genuinely never know for sure the nature or the timing of the onset of hominin fire-use; this is the reality of palaeoanthropology. Cross-cultural survey comparative research does support key aspects of FAF. FAF neatly fits within the nexus of hominin adaptations identified by Dunbar et al. 2014. While FAF is not specifically necessary for accelerated ancient hominin cultural evolution, it does elucidate specific pathways as to how it may have occurred. Nutritional and energetic budgets are theoretically balanceable through Wildfire Package affordances available within both physical and mental landscapes.

Survey data were analysed in depth and certain trends were found to be in accord with expectations, some of which were then ascribed as behavioural relics. As predicted the Batwa cohort had significantly more positive framing of fire than other cohorts. A point that needs to be considered here is that while survey fieldwork has identified the cross-cultural usefulness of fire the data cannot address the question of whether the usefulness of fire is a 'modern behavioural relic' (perhaps stemming from prevalent Mode 3 fire behaviour such as the use of fire for hafting or glue-making [Roebroeks and Villa 2011], or 'fire-stick farming' [Jones 1969]) or a 'very ancient behavioural relic' as proposed by FAF. FAF may not be proven but every effort has been made to test it. Perhaps the only way of answering the question 'Can the FAF hypothesis be considered robust?' is to further test aspects of it.

Future direction and closing remarks

One major issue in the field of palaeoanthropology is that few palaeoanthropological hypotheses posed are presented in testable terms. The nature of palaeoanthropology results in few hypotheses being precise enough that ideas can be taken beyond ‘argument by plausibility’ to empirical testing. It is acknowledged here that while FAF *is* grounded in ‘argument by plausibility’ attempts have been made within this study to empirically test the hypothesis by creating a unique innovative methodology and surveying the attitudes to fire of three diverse modern populations including the Ugandan Batwa. This is a PhD study (by definition with limited resources) and so will probably not have empirically tested the FAF hypothesis to the satisfaction of all researchers; significant scope exists for further testing and future work. In particular the FAF pathway related to nurseries, caregivers and dependents (outlined at the end of Chapter 7) requires empirical testing. A recap on the analyses shows that gender and age do not stand out as important in this study’s results; but they could be in other circumstances, so it is important to highlight them for further study.

To corroborate the conclusions drawn in this study it seems of particular importance to deploy similar questionnaire based methodologies (with perhaps the odd methodological tweak) on other African hunter-gatherer communities such as the Hadza, Efe or Sua; the more ‘traditional’ or unaltered by modern life and technologies their lifestyle is the better for being able to identify ancestral behaviours. It appears of paramount importance to always clearly explain (as was done in this study) to participants from traditional societies what the research is about, why this data is being collected and that the exact same research is being undertaken on participants from other cultures so that they do not feel that they are being seen as museum relics or objects of curiosity. Consistent feedback received from Batwa elders during data collection from this study was that the use of ethnic Batwa translators and logisticians was of fundamental importance to gaining the number of respondents that we recruited as well as the quality of data obtained (a large debt of gratitude is owed to the Batwa who assisted with data collection, without them data collected in this study would have been of lower quality and lesser quantity). Future research should follow this example; time, effort and resources should be invested to trust and train indigenous researchers.

With respect to future research conducted in the UK into attitudes to fire a lot of opportunity exists to generate greater precision of data on the nature of fire-based LOFs. Cross-cultural research looking at differences between people who live in close proximity but with different lifestyles, such as farmers and commuters, may help to show how lifestyle and personal experience with fire impacts on people's framing of fire. Work done in this study with the two African cohorts shows how different communities, who are geographically proximal but with vastly differing lifestyles, can frame fire so differently.

This study suggests future research not just in the area of fire but in public health and a myriad of other settings where aspects of physical landscapes map onto mental landscapes. This may be in the design of work-spaces such as offices or government buildings, public spaces such as parks or hospitals or commercial spaces such as nightlife environments (where making people feel comfortable can make commercial sense as well as reduce harms and risks); all of which can benefit from better more intelligent design. Mental health issues are very much in vogue now and a lot of scope exists to use landscapes of fear theory and analysis, and the knowledge that they are to some extent controlled by hominin evolutionary history, to help improve the mental wellbeing of modern populations who possess neural architecture that was not designed for the environments in which they live and the technologies that are now intrinsic to modern Western lifestyles (and also now more so in many developing countries as well).

While the origin of the genus *Homo* remains poorly understood (Bobe and Behrensmeyer 2004, Anton et al. 2014) the transition to *Homo* from the ancestral state has been suggested to have incorporated many behavioural and landscape use changes including a trophic repositioning (Vasey and Walker 2001) (i.e. a rise in trophic level) necessitating a range of different strategies (e.g. foraging and risk reduction) that would require hominins to evolve new adaptive ways of thinking and framing their world. Successful tool using hominins living in the midst of fluctuating climates can be surmised as having elevated levels of adaptability and plasticity in behaviour relative to antecedents with less broad toolkits. Plio-Pleistocene African terrestrial environments were a dangerous place (Sterelny 2012). Those that selected the best landscape optimisation strategies would have been able to outcompete, and attain greater biological fitness than, other groups or species. Interestingly this research does not support the Pyrophilic Primate hypothesis. As it was not a goal of this project to test the Pyrophilic Primate hypothesis (the construction of FAF and subsequent surveying predates publication of the Pyrophilic Primate hypothesis), what this does perhaps show is precisely how important it is to have actual studies of modern perceptions, attitudes and framing of fire with which to test aspects of hypotheses concerning early hominin fire-use.

In this study the preferential exploitation of the Wildfire Package is placed at the heart of the transition into *Homo* to see if an 'elegant fit' can be made with other available data. We conclude that although strong or direct tests are difficult with current data, FAF provides a far-reaching and integrative explanation for the onset of hominin fire-use that is consistent with evidence from a wide range of disciplines; including surveys conducted as part of this study. Winder et al. (2013; P6) point out that any convincing hypothesis of hominin evolution must be able to *'explain the appearance of key human adaptations like large brains and bodies, manual dexterity, advanced tool use and changes to life history, which together form* *an adaptive suite of interlinked characteristics*'; FAF while not being able to explain the appearance of every one of these traits does neatly fit within a nexus of these traits.

FAF provides contextual support for many key hominin adaptations and is capable of generating adaptive-selective forces that 'feedback with', ratchet and drive the appearance and stabilisation of many of these traits in line with established evolutionary theory (some of FAF's key insights and mental adaptations perhaps help to amplify certain selective forces thus driving feedbacks). The initial uptake of hominin fire-use, in the way described by FAF, places affordances of the Wildfire Package and innovative adaptable hominin fire-use strategies at the heart of the nexus of behavioural plasticity, variability selection, and innovative tool use that appears to pre-empt the initial appearance of *Homo*. This may have been complete innovation or strengthening of even more ancient pre-existing relationships (e.g. the very deep root of fire discussed in Chapter 2).

Throughout this report it has been argued that perhaps the original hominin fire was not the cooking fire, the hunting fire or the protective fire, but the 'fire in the mind' linked to 'fire on the landscape'. Perhaps it's now time to view lithic technology as simply an archaeologically visible aspect of Pliocene hominin toolkits that included the earliest deliberate hominin interactions with the Wildfire Package. The use of fire as a 'tool in the mind' and a 'tool in the hand' would have been a crucial juncture in human history; if it were at least partly driven by adaptations in mental landscapes, as has been proposed (and tested for) in this study, then evolutionary psychology suggests some imprint of this adaptation would remain.

The data collected in this study is in general agreement with the predictions of the Fear and Flames hypothesis regarding the nature of modern human positive attitudes to fire and particularly how it is framed within the nexus of risks and benefits. The simplicity of FAF enables clear thought to be given to the specific nature and strength of adaptive selective forces. The data generated in this study is here assessed as providing credible evidentiary support to the FAF hypothesis. It is argued here that FAF explains the key events of the earliest hominin fire interactions better than previous models resulting in a hypothesis that is non-teleological, is plausible from the perspective of contemporary hominins and does not result in obligate fire behaviour at implausible time periods or places. It is hoped that future work will be undertaken along the theoretical lines of reasoning used in this study and that a new more nuanced and realistic paradigm will eventually emerge and stabilise that places hominin fire-use centre stage in the construction of the initial niches of *Homo* and the adaptive selective forces driving the emergence of the genus *Homo;* Medler's (2011) '*fire creatures*'.

Appendix A: Fieldwork at Florisbad and Soetdoring

Notes: The principal investigator would like to acknowledge that throughout this fieldwork, it was always front-of-mind that observations were not being made on the same landscapes as those inhabited by ancient hominins.

Data and results from fieldwork are not presented here as it was deemed that to include all of the data and discussion about the methodology and results would be both superfluous to this thesis and a distraction from the material focussed upon. Where observations are relevant they have been included within the main body of this study. Some material from this research has been prepared for publication (Gowlett et al. in press) with other publications planned for the near future.

Therefore it was decided to include in this appendix only sufficient information to contextualise the observations discussed in the main body of text. This includes: i) The location of fieldwork sites; ii) Brief descriptions of the habitat; iii) A brief discussion of why this kind of research has a lack of capacity to create reproducible results and therefore can be classified in some circles as ‘lacking credibility’.

Fieldwork sites

At the start of the Austral winter of 2012 six weeks was spent conducting fieldwork in the Free State in the central interior of South Africa. All personal fieldwork observations presented in this study were obtained at two different locations; Florisbad Research Station and Soetdoring nature reserve.

Florisbad Research Station is ~0.94 Km2 in size, is the site of a natural thermal spring and is also the location from where the ‘Florisbad skull’ (either ‘archaic *Homo sapiens*’ or *Homo heidelbergensis*) was discovered, protruding from the spring itself, by Prof. T.F. Dreyer in 1932. Soetdoring Nature Reserve is a small nature reserve that covers approximately 75 square kilometres (29 sq mi) and is located about 7km from Florisbad Research Station.

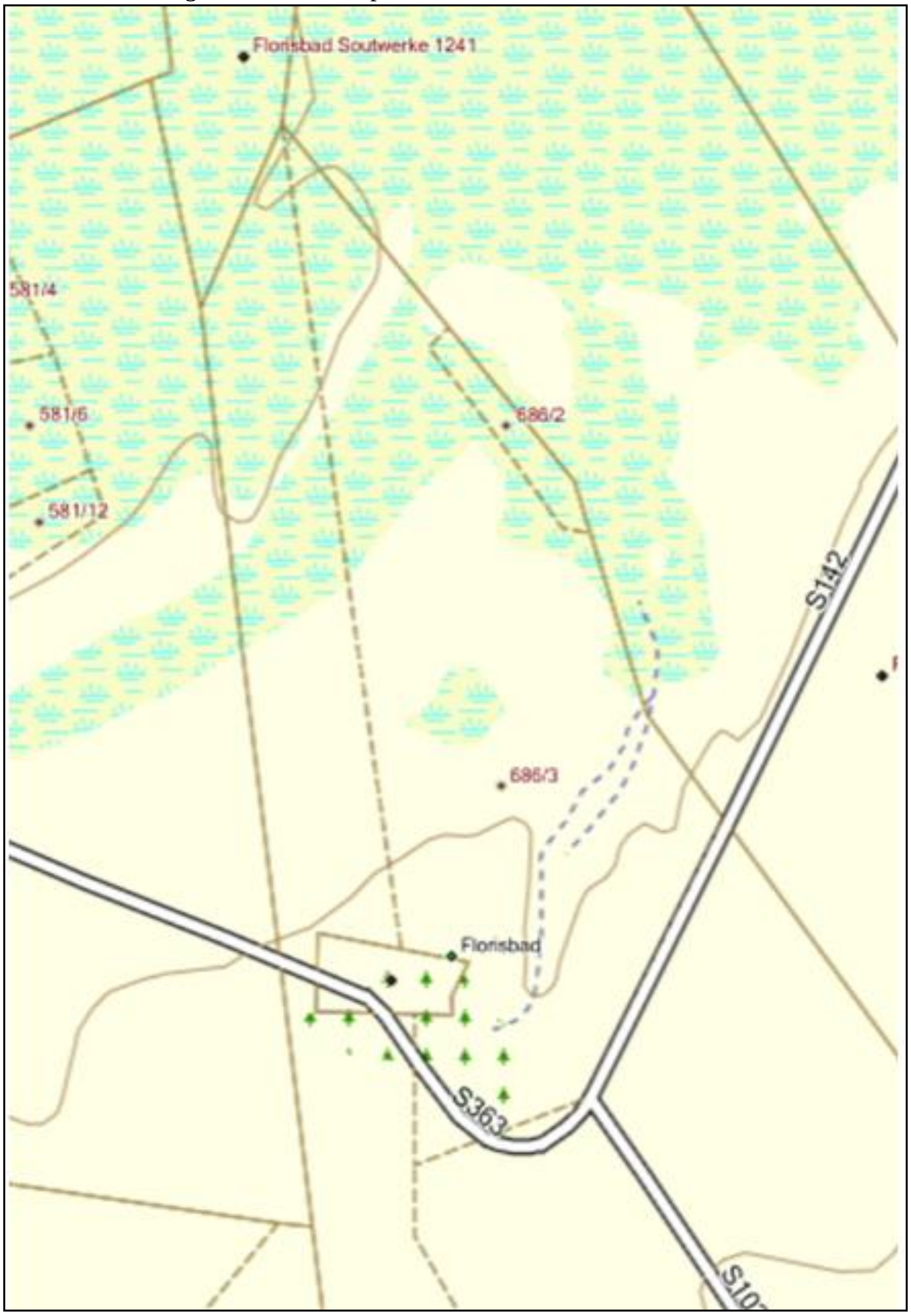
Florisbad Research Station

The Florisbad fossil site (28°46'S; 26°04'E) situated ~45 km NNW of Bloemfontein in central South Africa, at an altitude of ~1250m, consists of a sequence of Quaternary deposits associated with a thermal spring. The vegetation is typical ‘Dry-Sandy Highveld Grassland’ (Avenant 2005). Mean annual precipitation is ~450mm, and mean daily maximum and minimum temperatures ranges from ~ 31°C and 14°C in January to c. 16°C and -1°C in July (Avenant 2005). A slight gradient is present on the landscape with the research station sited on the highest ground with the 94-hectare plot stretching down to a saltpan to the north. The site is frequently used by a number of researchers from different fields, for example small mammals are sampled during late summer and late autumn researchers from the National Museum Bloemfontein. A number of different diverse habitats within the Florisbad Research Station grounds have been identified: i) Exotic *Kikuju* sp. grass and *Eucalyptus* sp. Trees (28°46.052'S; 26°04.248'E); ii) Open eroded area (28°46.044'S; 26°04.303'E); iii) Low bushes on post-climax grassland (28°45.893'S; 26°04.243'E); iv) Vegetation (mostly sedges) around a swampy area (28°46.045'S; 26°04.268'E); v) ‘Open’ *Themeda triandra* grassland (28°46.039'S; 26°04.352'E); vi) ‘Dense’ *Themeda triandra* grassland (28°45.910'S; 26°04.186'E). Vegetation at Florisbad prior to burning was patchy with occasional dense stands. The entire site is heavily anthropogenically influenced, however habitats i) and ii) are considered the most influenced by man, and sites v) and vi) the least (Avenant 2005).

At neither Florisbad Research Station nor Soetdoring Nature Reserve was a ‘natural wildfire regime’ present. At Florisbad Research Station the prevailing management plan over the previous 12 years had been to have zero fires; this had been successful. This had been achieved through rigorous anti-fire health and safety policies. It was established through conversations with park rangers at Soetdoring Nature Reserve that a mix of anthropogenic and natural ignitions drove the fire regime within the reserve. It is interesting to note that within one week of arrival at Florisbad a natural conflagration occurred at Soetdoring (before I had even visited the reserve). During my six weeks research a total of six ‘controlled’ burns occurred at the Florisbad Research Station and one natural wildfire occurred at Soetdoring Nature Reserve. The final ‘controlled’ burn at the Florisbad Research Station became uncontrolled due to a mixture of arrogance and poor logistical planning from local senior management staff. All protocols asked by the University of Liverpool ethics committee were adhered to and all risk assessments had been undertaken and followed; no blame was attached to any researchers from the University of Liverpool. No people or livestock were injured but it was decided by mutual consent to not conduct any further burning experiments at the Florisbad Research Station in 2012 until new equipment was acquired and staff had undertaken further training.

The burns conducted at Florisbad were specifically aimed at restoring native vegetation and resetting plant successions, rather than for this research. Burns were made towards the end of the Austral winter, and before the rainy season commenced. Anecdotal evidence gained from numerous sources across the African continent, and also backed up by published material (e.g. Johnson 1992), suggests that lightning ignited fires are most likely to occur in the transition from dry to wet seasons. Vegetation at Florisbad was in a similar state of desiccation as would be expected of an African savannah/bushland environment at the end of a dry season; the majority of grass was between 20-50 cm in height, but a number of sporadic patches reached up to ~1m in height.

Figure A1: Two maps of the Florisbad Research station



Material was easily ignited (on two occasions five matches was sufficient to create a 'fire front'), and was ignited and then burnt in a wind-driven moving fire-front formation; researchers and staff were on hand to make observations and physically intervene if deemed necessary by local managers. Fire was directly observed in low scrub and savanna/riparian woodland including groups of trees of up to 8 metres in height (Gowlett et al. in press). Measured wind-speeds were low while burning, always less than 10 km/h; anything higher than this was identified in risk assessments as too dangerous. With the exception of one burn, the last burn, fire fronts moved relatively fast, most burning took place within the space of a few minutes. Burns lasted less than one hour even in the case of trees (Gowlett et al. in press). Temperature data was collected using thermocouples with long leads.

Soetdoring Nature Reserve

Soetdoring Nature Reserve (28°.83'S; 26 °.06'E) is owned and managed by the government of South Africa. The Soetdoring Nature Reserve flanks a reservoir and is situated about 40 km north of Bloemfontein while the public entrance is approximately 7km from Florisbad Research Station. Soetdoring Nature Reserve covers approximately 75km^2, is part of the Grassland Biome of the 'sweet veld', and encompasses three distinct ecosystems: wetland, thornveld and grassland, each of which has their own characteristic flora and fauna. Larger trees are found towards the river, including sweet thorn (soetdoring – which give their name to the reserve), a species of Acacia (Gowlett et al. in press). The nature reserve is home to a wide range of large mammals, mostly grazers and browsers such as gemsbok, eland, springbok, blesbok, black wildebeest, zebra, red hartebeest, impala, kudu, steenbok, duiker and mountain reedbucks which all roam freely; larger carnivores (e.g. cheetahs and lions) are present only within special large enclosures. Soetdoring is also home to nearly 300 bird species as well as a wide assortment of small mammals, insects (and many other species of invertebrates) and snakes.

Whilst researching for this study a broad range of observations and investigations were made on two bushfires and their attendant landscapes: i) a burn of July/August 2012, about six weeks old at the time of observation; and, ii) a fire dated to September 10th 2012, observed at the end of the burn and through the following two weeks. A further fire was also observed on September 23rd 2012 (see Gowlett et al. in press for more details) (see Fig. AA2). In several instances entire trees had burnt right back into their roots, creating fire baked zones up to two metres across, which resulted in fire persisting on the landscape for large amounts of time; in one instance a temperature of over 700^{O}C was observed with the thermocouples two weeks after the initial conflagration. This observation allows the possibility that ancient hominins could easily have been drawn to these features, available over a long period of time, which could have been exploited in a broad variety of ways.

Figure A2: approximate outlines of fires observed at Soetdoring Nature Reserve in 2012.

The difficulties of conducting robust fieldwork with fire

The development of an understanding of the effects of fire can be supported by research based on the experimental application of selected fire regimes on fixed areas (Van Wilgen et al. 2003). Results of experimentation on fire obtain credibility due to their (usually) long-term duration, with treatments often repeatedly applied over many decades (e.g. research undertaken at Kruger national Park SA) (Van Wilgen et al. 2003). Within the literature experiments reflect the prevailing thinking of the time of their initiation and as such may not be relevant in research focus to this study. To avoid problems around scale, variability, replication and control that commonly plague biological experiments explicit consideration of the key components of experimental design is required: controls, replication, randomisation, and interspersion (Campbell and Reece 2005). Running robust fieldwork with fire therefore requires significant resources not accessible to study.

Not all fires in savannah ecosystems have the same characteristics (Bajocco et al. 2010); acknowledging this makes experimentally studying fire very difficult. Fire studies are highly resource intensive due to the fact that the ecological effects of a single fire or the cumulative effects resulting from the imposition of a fire regime may be quite different (Parr et al. 2004). Long term studies are seen as particularly valuable since subtle short-term changes may only become detectable once a certain threshold has been reached (Parr and Chown 2003) and because long term studies are more likely to detect long-term ecological responses (Parr et al. 2004); therefore, the ecological effects of an individual fire may be quite different from those resulting from a fire regime. Importantly also the repetitive application of fire to a site allows for replication of results. Short-term experiments have been identified as especially prone to a conclusion of no effect (Parr and Chown 2003). Fire has an impact on fauna through the effects of given fire events, and the cumulative effects resulting from the imposition of a fire regime, where a consistent sequence of several fires has been applied to an area (Van Wilgen et al. 2003). As the direction and magnitude of response to a disturbance may differ temporally, short-term observations of a system (especially in variable environments such as savannahs) do not necessarily provide a useful estimate of long-term impacts (Van Wilgen et al. 2003).

In short-term studies experimental limitations often compromise the robustness of findings (Parr et al. 2004), which explains why in this study (where the opportunity to deploy a multi-site, multi-burn experimental design was not attainable) all ‘data’ is classed purely as ‘personal observation’. This was not a surprise as from the onset it was known that insufficient time and resources existed to allow a robust experimental design that would counter the problems of scale, variability, replication and control and therefore all results would only be personal observations that would be relevant to that particular fire event. This did not make the research worthless as (as hoped) this research acted as a catalyst to aid theoretical exploration of the earliest hominin fire interactions.

Appendix B – Cross-cultural questionnaire on modern attitudes to fire

First, please tick this box to show your consent to participate in this study ☐

1. Please look at each pair of words below and place a cross in the space between them to show ***how you feel about fire***. The closer your cross is to one word the more ***you feel*** that option. Placing a cross in the middle means you think both words apply equally to how you ***feel about*** fire.

Risky		Protective
Exciting		Dangerous
Burning		Warming
Violent		Social
Safe		Scary
Hazardous		Useful
Comforting		Stressful
Friendly		Fearsome
A gift		A threat
Attracting		Repelling
Cleansing		Destructive

2. Have you used fire (where you can see a flame) for any of the following reasons? (Please tick all that apply)

	Yes		Yes
Keeping insects away	☐	Cleaning and cleansing	☐
Cooking food	☐	Boiling water	☐
Keeping warm	☐	Killing plants	☐
Light	☐	Burning rubbish	☐
Signalling	☐	Making things	☐

If you have used fire for any other purposes, please tell us what these are:____________________

3. Have you ever been burnt by fire? Yes ☐ No ☐

If yes, please place an X between the two options below to indicate how severe your worst burn was.

Very slight	Very severe

About you:

4. Are you: Male ☐ Female ☐

5. How old are you?
18-24 ☐
25-34 ☐
35-44 ☐
45-54 ☐
55-64 ☐
65-74 ☐
75+ ☐

6a. Do you have children? Yes ☐ No ☐ (if no go to Question 7)

6b. If yes, how old is your youngest child? ☐

7. From birth to the age of 10 did you mostly live in a rural or urban environment?

Rural ☐ Urban ☐

8. From the age of 10 till 18 did you mostly live in a rural or urban environment?

Rural ☐ Urban ☐

9. Do you now live in a rural or urban environment?

Rural ☐ Urban ☐

10. Do you smoke? Yes ☐ No ☐

11. Have you ever smoked? Yes ☐ No ☐

Many thanks for taking the time to complete this survey.

Appendix C – UK and NBA Participant Information Sheet

UNIVERSITY OF LIVERPOOL

Participant Information Sheet

Exploring the attitudes towards, and perceptions of, fire within modern human populations: a questionnaire data collection exercise

Researchers:
Mr Adam Caris: PhD student; Archaeology, Classics and Egyptology
a.caris@liv.ac.uk
Professor John Gowlett; Archaeology, Classics and Egyptology
gowlett@liverpool.ac.uk

You are being invited to participate in a research study. Before you decide whether to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. If you would like more information about the study before deciding whether or not you'd like to be involved please email one of the researchers involved in the study using the email addresses above. Please also feel free to discuss this with other people if you wish. We would like to stress that you do not have to accept this invitation and should only agree to take part if you want to.

What is the purpose of this study?

This is a study in which we are trying to find out how people's feelings and attitudes about fire are affected by the experience they have personally had of fire.

Why have I been chosen to take part?

You have been chosen to take part because this will eventually be a cross-cultural study and we need some baseline data from participants in the UK.

Do I have to take part?

It is entirely up to you whether or not you take part in this study. If, after reading this information sheet you decide not to take part, you can simply tell the researcher that you are not interested. If you do decide to take part but then change your mind you can stop at any time and simply tell the researcher that you do not want to do any more. You do not have to give any explanation and you will not be disadvantaged in any way by doing so. You can, if you like, request that any information you have provided up to this point be deleted.

What will happen if I take part?

This is a questionnaire exercise. You will be asked to self-complete a quick form and return it to the researcher.

Are there any expenses and or payments for participating?

You will not be reimbursed for your time and expenses in relation to your participation in this study.

Are there any risks in taking part?

There are unlikely to be any significant risks involved in taking part in this study. However, if you are not comfortable answering questions about your attitudes and experiences of fire then it would be best for you not to participate. There are no images or photos as part of this study, and no fire will be present during the study. Please be mindful that there are no direct benefits to you for taking part in this study.

What if I am unhappy or if there is a problem?

If you are unhappy, or if there is a problem, please feel free to let us know by contacting John Gowlett on 0151 794 5045 or Gowlett@liverpool.ac.uk and he will try to help. If you remain unhappy or have a complaint which you feel you cannot come to us with then you should contact the Research Governance Officer on 0151 794 8290 (ethics@liv.ac.uk). When contacting the Research Governance Officer, please provide details of the name or description of the study (so that it can be identified), the researcher(s) involved, and the details of the complaint you wish to make.

Will my participation be kept confidential?

Any information you provide will be kept in confidence and only the researchers directly involved in the project will see your information. Your set of responses will be allocated a numerical code and entered into a secure database. The database will be kept on secure drives at the University for up to 5 years whereupon it will be deleted.

What will happen to the results of the study?

The results of the study will be written up in the form of a PhD thesis by Mr Adam Caris. It I also possible that the results will form part of a publication in a peer reviewed academic journal. No identifying information will be used in these projects or publications

What will happen if I want to stop taking part?

You can withdraw from this study at any time, without explanation. Any information you have provided up to the period of withdrawal will be used by us unless you indicate that you would like your information to be deleted.

Who can I contact if I have further questions?

If you have any further questions about this research please contact John Gowlett, on 0151 794 5045 or Gowlett@liverpool.ac.uk

Appendix D - Rutwa translations used when interviewing Ugandan Batwa respondents

English	Rutwa
Risky	Akateezo
Protective	Kwirinda
Exciting	Kushemeza
Dangerous	Ekyibi
Burning	Kwosya
Warming	Gushuusha
Violent	Okuyomba
Social	Omubano
Safe	Obuteeka
Scary	Gutinyisha
Hazardous	Ekigwererezi
Useful	Ikyakamaro
Comforting	Okuhumuriza
Stressful	Ebitekyerezo
Friendly	Omunywani
Fearsome	Kutinyisa
A gift	Igihembo
A threat	Kukanga
Attracting	Ekyibonire
Repelling	Kugangurayo
Cleansing	Okuboneeza
Destructive	Okushisha

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