Can DAVE (Dog-Assisted Virtual Environment) be used in the assessment of human behaviour towards dogs?

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

by

James Andrew Oxley

September 2023

TABLE OF CONTENTS

Contents **Page no.**

DIGITAL CONTENT

The digital content includes:

- A video of the VR user experience in the Dog-Assisted Virtual Environment (DAVE)
- Survey questions for chapters 4, 5, 6, 7 and 8.

The digital content can be viewed here: https://tinyurl.com/JOxleyPhDDigital

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Can DAVE (Dog-Assisted Virtual Environment) be used in the assessment of human behaviour towards dogs?

James A. Oxley

Despite the popularity of pet dogs and their broad benefits to humans, there are also disadvantages of human-dog interactions, such as human-directed dog aggression potentially resulting in injury or death and/or psychological distress. Such incidents may also impact the welfare of dogs as they may be punished, rehomed, abandoned, seized or euthanised. While there are many contributing factors leading to dog bites, little research to date has explored human behaviour in the presence of dogs displaying aggressive behaviour, due to the ethical and practical implications of conducting such research in real life scenarios.

To address this, a virtual reality (VR) dog model was developed by VR and animation experts at the Virtual Engineering Centre UK, with input from qualified dog behaviourists. DAVE (Dog-Assisted Virtual Environment) was developed to display "aggressive" and non-reactive behaviours. The "aggressive" behaviour was based on the Canine Ladder of Aggression model. The size, colour, environment and audio of the dog could be modified and an indoor (house) and outdoor (park) environment was available. Both the VR dog model (VR tasks) and videos of the virtual dog model (online survey) were used to assess human behaviour and their ability to interpret dog behaviour. This included evaluating differences in participant approach-stop distance around the two different virtual dogs, varying colour, size, environment, audio and participant characteristics. In addition, DAVE was used to assess the effectiveness of veterinary student training in animal behaviour and handling.

Participants were able to use the VR equipment with limited instructions needed and user responses indicated that there was no evidence of simulator sickness during the VR tasks. Presence scores were rated as high demonstrating evidence of suitable immersion in the virtual environment. Participants regarded the dog models behaviour and appearance to be similar to that of a real dog, whether in VR or watching videos. Participants moved closer to the non-reactive dog model compared to the aggressive dog model. Participants also moved closer to the dog model if they were male, had less experience with dogs or if the size of dog was small. Whereas there was no evidence of a difference in how close participants got to the medium sized, yellow dog model displaying aggressive behaviour when comparing audio (presence versus absence) or environment type (indoor versus outdoor). There was no evidence of a difference in approach-stop distance based on coat colour (yellow and black). Participants most frequently blamed themselves or the owners for the dog's behaviour and rarely the dog, similar to real-life scenarios. Veterinary students moved closer to the virtual dog before their teaching and training sessions than after.

This research demonstrates that DAVE can be used to assess aspects of human behaviour in the presence of a virtual dog model and provides further insight into human interpretation of specific dog behaviour signals which may aid in dog bite prevention education and training. Given that this is the first model of its kind, based on expert feedback and a theoretical dog behaviour model, these results are encouraging and highlight the need for future work with a broader range of participants, particularly those that are at a higher risk of dog bites.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my primary supervisor Dr Carri Westgarth for her guidance from the start to the end of my PhD, attention to detail, detailed comments and feedback and ultimately resulted in me improving the quality of my writing and research.

I would like to thank Dr Georg Meyer and Dr Andrew Levers, my secondary supervisors, who provided constructive criticism and comments throughout my PhD.

I would also like to thank:

The VEC (Virtual Engineering Centre) were fundamental in this research project in developing the virtual dog model (DAVE) and this research would not be possible without them. Specifically, I would like to thank, Giuseppe Bellantuono, Iain Cant, Andrew levers, Matthew Butcher and any other staff that were involved in the dog model development.

To my wife Clare who I got engaged to and married to during my PhD. Thank you for all your support {W}.

To my father, Alan, for encouraging me to work hard and for all the support, discussions and advice about research.

My dog Rosie, who kept me company during my PhD and COVID, got me out of the house and never fails to make me laugh.

The Dogs Trust for funding this research and their advice.

My internal and external examiners for their detailed comments on my thesis.

Finally, I would like to thank all students and the public that took part voluntarily in practical sessions and surveys and the University of Liverpool administration staff.

RESEARCH OUTPUT

CHAPTER 2

- **Paper: Oxley, J. A.**, Santa, K., Meyer, G. and Westgarth, C. (2022). A systematic scoping review of human-dog interactions in virtual and augmented reality: The use of virtual dog models and immersive equipment. *Frontiers in Virtual Reality*, 3, 782023.
- **Poster: Oxley, J. A.**, Santa, K., Meyer, G. and Westgarth, C. (2021). A systematic scoping review of direct human interaction with virtual and augmented reality dog models, model quality, and equipment used. *Canine Science Forum*, Online. 6th-9th July 2021.

CHAPTERS 3 & 4

- **Paper: Oxley, J. A.**, Meyer, G., Cant, I., Bellantuono, G. M., Butcher, M., Levers, A. and Westgarth, C. (2022). A pilot study investigating human behaviour towards DAVE (Dog-Assisted Virtual Environment) and interpretation of nonreactive and aggressive behaviours during a virtual reality exploration task. *Plos One*, 17, e0274329.
- **Presentation: Oxley, J. A.**, Meyer, G., Cant, I., Bellantuono, G. M., Butcher, M., Levers, A. and Westgarth, C. (2021). A pilot study investigating human interpretation and behaviour in the presence of a virtual reality dog model (Dog-Assisted Virtual Environment) displaying aggressive and unresponsive behaviours. *International Society for Anthrozoology*, Online, 22nd-24th June 2021.

CHAPTER 6

- **Presentation: Oxley, J. A.**, Meyer, G., Cant, I., Bellantuono, G. M., Butcher, M., Levers, A. and Westgarth, C. (2021). Do people differ in their stopping distance when approaching an aggressive and unresponsive simulated dog model with and without sound*?*. *Canine Science Forum*, Online, 6-9th July 2021.

CHAPTER 7

- **Poster: Oxley, J. A.**, Meyer, G., Cant, I., Bellantuono, G. M., Butcher, M., Levers, A. and Westgarth, C. (2022). The effect of dog colour, size and environment on a human approach-stop task using videos of a simulated dog model displaying aggressive behaviours. *Universities Federation for Animal Welfare*, Edinburgh, UK. 28th-29th June 2022.
- **Presentation: Oxley, J. A.**, Meyer, G., Cant, I., Bellantuono, G. M., Butcher, M., Levers, A. and Westgarth, C. (2022). An international survey investigating the role of participant demographics and dog related experience on approach behaviour to a simulated dog displaying aggressive behaviours. *International Society for Anthrozoology*, Online, 7th-9th July 2022.
- **Poster: Oxley, J. A.**, Meyer, G., Cant, I., Bellantuono, G. M., Butcher, M., Levers, A. and Westgarth, C. (2022). A human approach-stop task using videos of a simulated dog model displaying aggressive behaviours: The effect of participants demographics, dog model colour, size and environment. *International Symposium of Veterinary Epidemiology and Economics*, Halifax, Canada, 6th-11th August 2022.

CHAPTER 8

- **Poster: Oxley, J. A.,** Meyer, G., Cant, I., Bellantuono, G. M., Butcher, M., Levers, A. and Westgarth, C. (2021). Use of a simulated dog for the assessment of the effectiveness of a canine behaviour educational intervention in veterinary students. *World Small Animal Veterinary Association*, Online virtual conference, 13 – 15th November 2021.
- **Paper: Oxley, J. A.,** Meyer, G., Cant, I., Bellantuono, G. M., Butcher, M., Levers, A. and Westgarth, C. (2024). Veterinary students' proximity to and interpretation of a simulated "aggressive" dog before and after training. *Scientific Reports*. 14, 3209.

ACRONYMS

AR – Augmented Reality

CLA – Canine Ladder of Aggression

HMD – Head Mounted Display

IPQ – Igroup Presence Questionnaire

MR – Mixed Reality

PTSD – Post Traumatic Stress Disorder

SS – Simulators Sickness

SSQ – Simulator Sickness Questionnaire

VE – Virtual Environment

VEC – Virtual Engineering Centre

VR – Virtual Reality

CHAPTER 1. GENERAL INTRODUCTION

1.1 Introduction

The domestic dog (*Canis familiaris*) (the term 'canine' hereafter refers to the domestic dog) was the first species to be domesticated by humans according to both archaeological and genetic evidence. Although it is continuously debated, the indication is that domestication occurred, on multiple occasions, somewhere between 14,000 – 33,000 years ago (Ovodov *et al*., 2011; Thalmann *et al*., 2013; Wells, 2017). During proto-domestication wolves with lower levels of fear and aggression were more likely to successfully approach human settlements for food (Hare *et al*., 2012; Waller *et al*., 2013). During domestication, human selection pressures and preferences for reduced levels of defensive aggression towards humans and conspecifics are likely to have resulted in specific traits in dogs such as paedomorphic appearance and juvenile behaviour in comparison to wolves (Hare *et al*., 2012; Waller *et al*., 2013). Such paedomorphic physical and behavioural traits have also been seen to be the preference of potential dog owners in recent years possibly due to baby-schema (i.e. cute and vulnerable) and therefore selection maybe based on both behavioural (e.g. reduced aggression) and physical (e.g. shorter muzzle) traits are likely to have played a role in dog domestication and evolution (Waller *et al*., 2013). In the present day, there is a large morphological variation seen in domestic dog breeds as a result of intense selection by humans and there are currently 222 recognised pedigree dog breeds, each with distinctive morphological traits, in the UK alone (Kennel Club, 2022).

The popularity of the dog in modern day society is clear as there is an estimated population of between 700 million and one billion dogs worldwide, although estimations vary widely (Hughes and Macdonald, 2013; Lord *et al*., 2013; Macpherson *et al*., 2013, p. 9). The domestic dog is well established as a pet in western society to the extent where they are considered friends, confidants, protectors and family members (Guy *et al*., 2001; Kubinyi *et al*., 2009; Evans-Wilday *et al*., 2018; Martens *et al*., 2019). It is therefore unsurprising that pet dog populations in Europe and the UK are estimated to be 93 million (25% of European households) and 12 million (31% of UK households) dogs respectively (FEDIAF, 2021; UK Pet Food, 2023).

The human-dog relationship has been reported to be beneficial to both human physical (increased exercise, decrease cardiovascular disease, post-surgical recovery) and psychological (reduced depression, improved general mental health and happiness) health as well as aiding in human development, social interaction, and overall quality of life (Edney, 1995; McNicholas and Collis, 2000; Wells *et al*., 2004; Cutt *et al*., 2007; Knight and Edwards, 2008; Wells, 2019;

PDSA, 2022). However, it is important to note that some studies do not find such benefits of dog ownership (e.g. no link between dog ownership and mental health or wellbeing (Cui *et al*., 2021; Denis-Robichaud *et al*., 2022)).

The theories underpinning human-animal interactions, and why these can be beneficial to humans, have evolved over time along with other areas of the biological, psychological and social sciences. According to Beck (2014) and Fine and Weaver (2018) there are three accepted main theories that underpin human-animal interactions, and the benefits these provide, which include the biophilia hypothesis, attachment theory and the social support theory. Fine and Ferrell (2021, p. 27) proposes that the three theories overlap with one another as "joint theories" and should not be seen as individually distinct from one another. As discussed later, Gee *et al*. (2021) refers to the biopsychosocial theory with a specific focus on human-dog interactions.

The biophilia hypothesis, originally defined by Wilson (1984, p. 1), describes humans as having an "*innate tendency to focus on life and lifelike processes*". This hypothesis suggests that humans are genetically predisposed to be in the presence of, and interact with, nature and other living life forms. This theory can be applied to both positive (e.g. acquiring food) and negative (e.g. fear of a species that may cause harm e.g. snakes and spiders) aspects of human-animal interactions and ultimately is deemed to be beneficial for human survival (Fine and Mackintosh, 2016). However, Beck and Katcher (2003) note that it is difficult to differentiate between cultural and biological influences. For example, there are aspects of human-dog interactions which are not innate such as a human's ability to interpret dog behavioural signals accurately, which requires training (Meints *et al.,* 2018).

Attachment theory was developed based on human psychology and proposes that young children become emotionally attached to a primary caregiver over time for the purposes of care, safety and security and thus maintains close proximity to the caregiver (Bowlby, 1969; Bowlby, 1973; Ainsworth, 1978). It has been suggested that attachment theory can also be applied to human-animal relationships as similar emotional closeness is evident between humans and pet animals (Meehan *et al*., 2017) and in some cases pets have even been rated higher in attachment security in comparison to human adult partners (Beck and Madresh, 2008). Regarding dogs, in addition to humans being attachment figures for dogs as caregivers, there is evidence reporting that dogs can also be attachment figures for human caregivers and regarded as a source of safety for adults (Kurdek, 2009; Kurdek, 2009a; Schöberl *et al*., 2012; Zilcha-Mano *et al*., 2012).

Social support theory explains the emotional and physical support role that companion animals, including dogs, provide, similar to that seen in human social networks, as nonjudgemental confidents, friends and/or family members and therefore can provide a buffer to psychological stress (Turner *et al*., 2013; Beck, 2014; O'Haire *et al*., 2015). However, these benefits may relate to the strength of individual owner-pet attachment, i.e. those that are highly attached to their pets are more likely to consider their pet to be a form of social support (Meehan *et al*., 2017).

More recently, Gee *et al*. (2021) adapted the biopsychosocial theory, originally proposed by Engel *et al*. (1980), to apply to the human-dog interactions and highlights the three interrelated and dynamic factors (i.e. biological, psychological and sociological) that, either individually or in combination, can impact human health and wellbeing. However, it is important to note that evidence of an impact may occur at different time points, as Gee *et al*. (2021) provides an example of an individual's interaction with a dog resulting in a decrease in stress that may have an immediate biological effect (e.g. reduced blood pressure) but the psychological (e.g. improved mood) and social effect (e.g. increase in social interactions) may not have an immediate response.

Despite the range of potential benefits of human-dog interactions, there are also potential negative consequences to the public. These include zoonotic transmission, environmental damage/pollution by dog faeces (Rock *et al*., 2016), human injury as a result of tripping/falling over, being pushed over by a dog, or by a dog pulling when on a walk (e.g. chasing a cat, squirrel, another dog) (Stevens *et al*., 2010; Willmott *et al*., 2012; Forrester, 2020; Lowery and Rosen, 2020), as well as aggression towards humans (Casey *et al*., 2014; Oxley *et al*., 2018; Westgarth *et al*., 2018) and/or other dogs resulting in injuries to humans (Casey *et al*., 2013; Oxley *et al*., 2018; Montrose *et al*., 2020).

Dog aggression, whether it be directed towards humans and/or other dogs, is a commonly seen behaviour problems within dog shelters (Orihel *et al*., 2005), veterinary practices (Fatjo *et al*., 2007; Boyd *et al*., 2018), and behaviour clinics (Bamberger and Houpt, 2006; Col *et al*., 2016). For example, Anderson *et al*. (2022) reviewed 1800 dog behavioural cases from a US veterinary hospital over a twenty-year period (1997 - 2017) and found that most cases related to aggression (72.2%; 1300/1800), of which the majority was human-directed dog aggression (79.7%; 1037/1300).

Dog aggression directed towards humans (familiar, i.e. owner directed, or unfamiliar, i.e. stranger directed), also known as human-directed aggressive behaviour, is a commonly reported problem amongst dog owners and the general public and is regarded as a public health issue and welfare concern (see section 1.4) (Fatjo, 2007; Haug, 2008; Luescher *et al*., 2008). Dog aggression and dog bites directed towards humans can result in negative implications for human physical (Sacks *et al*., 1996; Kahn *et al*., 2003; Schalamon *et al*., 2006; Gilchrist *et al*., 2008; Rosado *et al*., 2009; Reisner *et al*., 2011; Westgarth and Watkins 2015; Oxley *et al*., 2018; Jakeman *et al*., 2020; Tulloch *et al*., 2021) and psychological health (Peters *et al*., 2004; De Keuster *et al*., 2006; Boat *et al.,* 2012; Dhillon *et al*., 2018) and dog welfare (Schalke, 2017; Oxley *et al*., 2018) (also see section 1.5 and 1.6). Furthermore, dog bite incidents can result in negative implications for the human-dog bond and have legal and financial implications at both an individual and community level (Haug, 2008; Hall *et al*., 2017, p.22; Tulloch *et al*., 2021).

To date there is a range of research investigating the assessment of human behaviour around dogs and, where aggression and dog bites are concerned, the majority is conducted retrospectively (e.g. via surveys, interviews, medical and/or veterinary records) (Schalamon *et al*., 2006; Shuler *et al.*, 2008; Reisner *et al*., 2011; Rezac *et al*., 2015; Westgarth and Watkins, 2015; Oxley *et al.*, 2018; Notari *et al*., 2020). Although the latter is of importance, limited research has been conducted on the real-time behaviour of humans in the presence of live dogs displaying aggressive behaviour as it is deemed unethical due to the potential for human injury and the potential negative impacts on canine welfare (e.g., causing fear) (Owczarczak-Garstecka *et al*., 2018). Therefore, human behaviour assessment in the presence of a dog displaying aggressive behaviours through novel methods which ensures both human safety and canine welfare, whilst being perceived as realistic, such as through the use of augmented reality (AR) or virtual reality (VR), is needed (see section 1.9 and chapter 2).

1.2 What is dog aggression?

In modern day society, dog aggression, although a natural behaviour, is often seen by human caregivers, even at low levels, as an abnormal, undesirable, problematic and/or dangerous behaviour (Keeling and Jensen, 2017; Boyd *et al*., 2018). This is especially the case, and potentially justified, when a dogs' aggression poses a potential risk of injury towards itself (e.g. self-directed aggression such as chewing or biting tail or hind leg) (Salgirli and Dodurka, 2011), another familiar or unfamiliar dog or human, and becomes difficult or dangerous to manage (Netto and Planta, 1997; Haug, 2008).

Aggression is a broad term and has been the subject of a range of theories and definitions, of which there is no strict scientific agreement in both human (Krahé, 2013, p. 8) and canine science (Mills *et al.,* 2014, p. 239). Despite this, in the context of research, Mills (2017) states that a definition of aggression is important in any study as, if no definition is provided, a reader is left to their own interpretation or perception of what aggression is. Broom and Fraser (2015, p. 361) broadly define aggression as "*an act or threat of action, directed by* *one individual towards another, with the intention of disadvantaging that individual by actual or potential, injury, pain or fear*". However, this definition refers to the 'intention' of an animal which is difficult to accurately determine and may be dependent on multiple factors (e.g., animal behaviour, context, etc). Whereas Overall (2013, p. 605) defines aggression as "*an appropriate or inappropriate, inter- or intraspecific threat, challenge, or contest, that ultimately results in either deference or combat, and in resolution*." Similarly, Hart *et al*. (2006) also notes the appropriateness of behaviour and notes that dog aggression can fall into two categories: 1) displaying 'normal' behaviour but deemed undesirable (i.e. due to societal pressure); 2) displaying 'abnormal behaviour' that is not consistent with the context or environment. However, both categories may be problematic when describing dog behaviour due to the broad and subjective nature of what is deemed 'appropriate', 'inappropriate', 'normal' and 'abnormal'.

Historically the term 'dominance', attributed to 'dominance theory', was previously deemed appropriate due to the assumption that an aggressive display towards owners was an attempt by the dog to challenge its position in the social hierarchy (Reisner, 2016). However, the use of the term has been challenged as not necessarily applicable, as at best it may only describe wolf or free roaming dog pack (>2 individuals) behaviour and there is no direct evidence to support relevance within the domestic dog-human relationship (Bradshaw *et al*., 2009; Mills and Zulch, 2010). More recently the term has also been viewed in a negative light due to the risks and repercussions as dog trainers and owners may attempt to be 'dominant' over their dog through punishment and other aversive training methods (Schilder *et al*., 2014; Reisner, 2016; Westgarth, 2016).

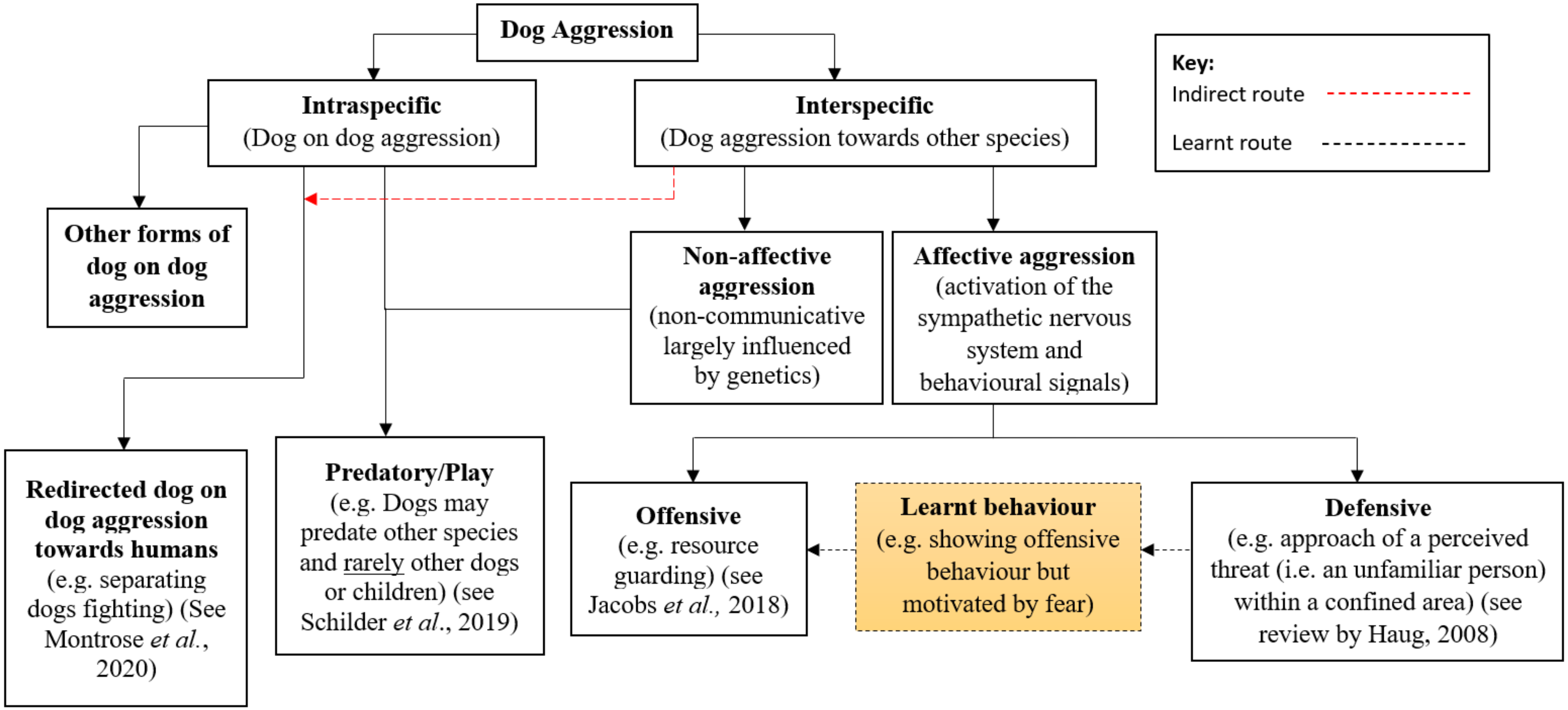
In dog related research, it is often stated that aggression is simply a term used to describe a group of behaviours and behavioural responses and does not indicate cause, motivation or emotion, nor is it a diagnosis (Bowen and Heath, 2005; Luescher and Reisner, 2008; Mills *et al*., 2014). For this reason, Mills *et al*. (2014) suggests that the term 'aggressive behaviour' may be a more appropriate term due to the need for the additional description of context, motivation and emotion. More recently, the range of dog (e.g. breed, sex, age, neuter status, genetics, behavioural and physical health) and owner related factors (e.g. dog management (diet, socialisation, training), attitudes, personality, owner experience, attachment level and interaction style) which may contribute to an increased risk of human-directed aggression are more understood as the field of canine behaviour and veterinary epidemiology has advanced (Flint *et al*., 2017; Newman *et al*., 2017; Gobbo and Zupan, 2020; Baslington-Davies *et al*., 2021). Additionally, another level of definition can be applied with regard to who the behaviour is directed towards, for example, dog aggression can be further divided into two categories - intraspecific and interspecific aggression (Lindsay, 2000). This research will focus only on the latter but more specifically human-directed dog aggression.

Dog aggression towards unfamiliar conspecifics or humans has been noted to be mainly caused by either, affective aggression or predation (Lindsay, 2000; Haug, 2008) (see Figure 1.1). Affective aggression (also known as social aggression) refers to the creation of distance between an individual and an active threat and can be either offensive (confident, e.g. a perceived challenge for a resource) or defensive aggression (fearful, e.g. an unfamiliar human approaching the dog) (Luescher and Reisner, 2008; Bain, 2009; Mills *et al*., 2014).

Affective aggression is influenced by multiple areas of the brain, including the ventromedial hypothalamus region and amygdala, resulting in a fearful experience leading to an aversive or aggressive response depending on the stimulus and context in which it occurs (Lindsay, 2001, p. 104). In contrast, predation or 'predatory aggression' has been previously regarded as 'nonaffective' behaviour, because it does not serve as a form of communication and relates to feeding/hunting behaviour and is even noted as being incorrectly labelled and not regarded as a genuine form of aggression (Bowen and Heath, 2005; Luescher and Reisner, 2008; Mills *et al*., 2014). Similarly, although play behaviour or 'play aggression' may result in injury (Owczarczak-Garstecka *et al*., 2018), it is related to predation and thus regarded as 'nonaffective' (Bowen and Heath, 2005; Mills *et al*., 2014). During predatory aggression, the lateral hypothalamus area, which is associated with feeding, is stimulated and therefore is likely to be a pleasurable experience (Lindsay, 2001, p. 103).

Generally, during defensive aggression, visual signals in the form of changed behaviour as well as vocalisations are displayed when a dog feels it, or its territory, is under threat (e.g. by an approaching human or conspecific) in an attempt to deter the threat, in turn avoiding potential injury (Manning and Dawkins, 2012; Broom and Fraser, 2015). Defensive aggression can be displayed in a broad array of behaviours ranging from subtle (e.g. lip licking or yawning) to more obvious (e.g. showing teeth or a physical bite) displays (see section 1.3) (Rugaas, 2006; Shepherd, 2009). Additionally, human directed aggression can be due to pathophysiological problems, such as pain or disease (Landsberg *et al*., 2013; Camps *et al*., 2019).

Figure 1.1 Categories and subcategories of interspecific and intraspecific dog aggression affecting humans.



1.3 The Canine Ladder of Aggression model

The Canine Ladder of Aggression (CLA) model, originally conceptualised by Shepherd (2002), is based on expert beliefs about the dog's behavioural repertoire in the presence of a significant stressor or threat (i.e. defensive aggression). The CLA model consists of 11 levels (Figure 1.2) with the lowest level of behaviour (yawning, increased blinking and lip licking) indicating appeasement (also known as 'calming signals') (Rugaas, 2006; Shepherd, 2009), but noted to not be entirely accurate when referring to defensive aggression as these behaviours are thought to be associated with the avoidance of conflict rather than 'calming' of an oncoming threat (Mills *et al*., 2013, p. 81).

The signals displayed are suggested to be an attempt to deter or avoid conflict and potential for injury with a posed threat (e.g. another dog approaching) (Shepherd, 2002; Rugaas, 2006). These early signs, such as lip licking, are likely to be the most frequently shown behaviours in dogs (Shepherd, 2009). Appeasement signals that are shown by dogs towards conspecifics are also shown towards humans (Rugaas, 2006; Kuhne *et al.*, 2016; Firnkes *et al*., 2017). For example, lip licking and looking away has also been noted to having been used in a similar way in interspecific interactions (Rugaas, 2006; Rehn *et al*., 2011; Kuhne *et al.*, 2016; Firnkes *et al*., 2017). However, it is important to highlight that these behaviours are also dependent on the context as yawning and lip licking may occur within other scenarios besides a threat (e.g. lip licking after eating, when in pain, when greeting a human or yawning before or after sleeping) (Luescher and Reisner, 2008).

In the CLA model, if a threat continues, and/or previously displayed signals are not seen or ignored, the dog will show additional and more intense behaviours to further indicate an aversion to a threat, for example, the tail being tucked underneath the dog's body, head turn and a paw lift, moving away and ears held back. Appeasement signals are the visual signals which are most often misinterpreted by humans (Kerswell *et al*., 2009; Mariti *et al*., 2012; Meints *et al*., 2018). Therefore, from a human-dog bite prevention perspective, humans need to be able to recognise these early signals to prevent the risk of injury. If a threat towards a dog continues, appeasement signals are escalated to behaviours indicating a direct threat in the form of a direct stare (NB: previously tried to avoid eye contact) alongside a growl, snap via a lunge and finally a bite occurs (Figure 1.2). This is especially the case if a dog is in a confined area and cannot escape or move away, such as a kennel, veterinary consultation room or a living room (Shepherd, 2009).

Meints *et al.* (2018) conducted a longitudinal intervention training study investigating young children (3-5 years) and adults' perceptions and interpretation of stress related behavioral signals in dogs. Sixteen short videos of dog behaviors, ranging from subtle yawning to the more obvious behaviors such as snapping and biting, were used. These behaviours were consistent with those described in the CLA model and were reviewed by behavioral experts. Participants viewed videos of dog behaviours and were asked to rate these on a five-point scale (very happy to very unhappy). The training was successful for adults across all three behavioural categories (1. conflict defusing such as lip licking, 2. conflict avoiding signals such as walking away, and 3. conflict escalating signals such as growling), although the subtle behaviors were the least frequently recognised. However, children were found to have increased knowledge about the more obvious stress signals (i.e. conflict escalating signals) after training, at six months and at one year after the training session, but there were limited improvements in knowledge for the children in regard to the more subtle stress signals (i.e. conflicting defusing such as lip licking and avoiding signals such as walking away). The study also found that older children were more likely to correctly identify stress signals than the younger children after the training, demonstrating the value of an educational intervention focusing on the range of dog behaviours described in the CLA.

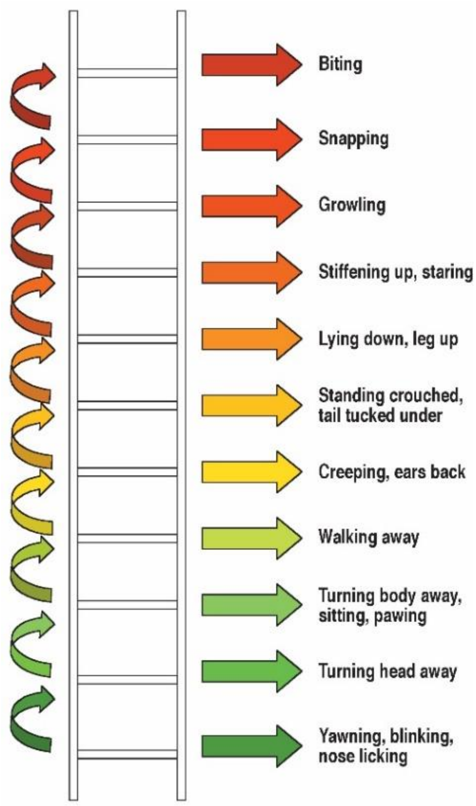


Figure 1.2 The Canine Ladder of Aggression model (Shepherd 2009; reproduced with permission from BSAVA, originally in the Manual of Canine and Feline Behavioural Medicine, 2nd edition ©BSAVA).

It should be noted that behaviours described in the CLA and their frequency may either not be displayed or be displayed but not in the exact order as described in the CLA as behaviours are thought to vary between dogs and the speed of escalation up the ladder may be due to the multiple factors such as context, health, past experience and/or learnt behaviours (Hedges, 2014; Meints *et al*., 2018). Furthermore, behaviours may simply stop escalating up the ladder due to stopping an interaction, conflict resolution or avoidance (Hedges, 2014; Meints *et al*., 2018). Furthermore, the accuracy of the term 'ladder of aggression' has been questioned due to: the possibility of behaviours not always occurring in a sequential order as steps of the ladder may be skipped; there are other steps not shown; progression up the ladder varies between individual dogs (Mills *et al*., 2013, p. 81). For example, Owczarczak-Garstecka *et al*. (2018) reviewed YouTube videos of human and dog behaviour prior to a dog bite and found that various dog behaviours, consistent with the CLA (e.g. head turning, staring, growling and snapping), increased in occurrence the closer the time to the bite. However, in contrast, the authors also found that yawning and lip licking appeared to occur but without a clear order (i.e., proximity). Having said this, the CLA appears to be a widely accepted model among canine behaviourists (Mugford, 2007, p. 229; Hedges, 2014, p. 50) and used by national animal charities (PDSA, n.d.), and dog bite prevention schemes (The Blue Dog, n.d.; Meints and De Keuster, 2009). Despite this, there is currently a lack of empirical data on professional opinions and the use of the CLA model.

1.4 Dog bite statistics and dog bite definition

The World Health Organisation (WHO) estimates that worldwide 'tens of millions' of people are injured as a result of dog bites each year (WHO, 2018). In rabies endemic countries which are also low- to middle-income countries (such as parts of Asia and Africa), dog bites are estimated to be higher than in high-income countries and are responsible for an estimated 59,000 deaths worldwide per year (Hampson *et al*., 2015).

Dog bites to humans make up most bite injuries seen in emergency departments in developed countries (Klaassen *et al*., 1996; Edens, 2016). In England, admissions to hospital as a result of being 'bitten or struck by a dog' have increased over the last ten years. For example, in 2008/9 and 2019/2020, dog bite admission figures in England were 5,221 and 8,859 respectively, an increase of 70% (NHS Digital, 2009; NHS Digital, 2020) (Table 1.1). Tulloch *et al.* (2021) also analysed hospital admission data in England between 1998 and 2018 as a result of being 'bitten or struck by a dog' and found that the incidence rate increased from 6.3 (6.12 – 6.56) to 15.0 (14.67 – 15.31) per 100,000 in 1998 and 2018 respectively. The rise in incidence rate was noted to be driven by an increase rate of adults being bitten, although dog bites to children remained constantly high over the twenty-year period (Tulloch *et al*., 2021). The rate of hospital admissions due to dog bites also varies between the regions in England, with the most deprived areas seeing the highest rates of admissions, the highest of which being reported to be Liverpool and Merseyside (NHS, 2015; Tulloch *et al*., 2021). A potential, although simple, explanation for such regional variations has been suggested to be due to the frequency of households which own a dog within these regions (Burt, 2016), for example, in 2019 the North West of England had the highest number of households which own a dog (PFMA, 2019). However, the factors affecting regional variation of dog bites are likely to be broad and more complex than simply regional dog ownership. For example, previous research has highlighted that hospital admissions in England as a result of being bitten or struck by a dog are highest amongst areas with higher levels of deprivation (NHS, 2015). However, this is not unique to dog bites as unintentional injuries in general are also known to vary with levels of deprivation, as seen with young children (Henery *et al*., 2021).

Of note, Orritt (2014) highlights that hospital admission figures do not distinguish between a 'bite' and a 'strike' under the incident code 'W54' for injury due to a dog. (The International Classification of Diseases (ICD) version 10, in which W54 is an incident code, is used because it allows for international comparisons to be made (Herbert *et al*., 2017)). In addition, Rollett *et al*. (2018) stated that hospital generated data may be prone to errors in coding for example, rather than an injury caused by a dog, maybe the recorder did not assign the injury to a specific animal. In addition, hospital figures are likely to be further underestimated due to victims of dog bites not seeking treatment, self-treating or seeking treatment from other sources (i.e. pharmacists, GP's etc) or an injury is deemed too minor to warrant medical attention (e.g. bruising, superficial wound) (Duffy *et al.*, 2008; Oxley *et al*., 2018; Westgarth *et al.*, 2018; Tulloch *et al*., 2021).

Previous medical literature has been found to misstate or exaggerate dog bite figures (Orritt, 2014; Arluke *et al*., 2017)., e.g. Morgan and Palmer (2007) incorrectly state 250,000 rather than the originally stated 230,000 dog bites by Thomas and Banks (1990). Despite this, previous research has found that approximately 50% of dog bites go unreported (Beck and Jones, 1985; Butcher and De Keuster, 2010). Wilson *et al*. (2003) surveyed parents about child-dog interactions and found that 20% of parents had reported a dog bite that had previously occurred to their own child. However, Spiegel (2000) conducted research which involved direct interviews with children and found that this figure may be substantially higher as 50% of children had reported previously being bitten, the majority (81%) of which was by a dog they knew.

Cornelissen and Hopster (2010) conducted a survey in the Netherlands and found that 62% (665/1,078) of bite incidents did not receive professional medical treatment either because no treatment was needed, or they sought treatment at home. Similarly, Oxley *et al*. (2018) conducted a UK public survey and found that 62% of self-reporting dog bite victims stated no medical treatment was required as a result of a dog bite. Westgarth *et al*. (2018) surveyed a community in the North West of England in 2015 and found that 24.8% (172/694) of individuals reported to have been previously bitten by a dog, of which, 33.1% stated that they required some form of medical treatment and only 0.6% needed hospital admission. Therefore, authors indicate that dog bites occur much more frequently (18.7 (95%CI 11.0–31.8) per 1,000 population per year) than previously reported in hospital admission figures (13.5 per 100,000) (Table 1.1).

Table 1.1 Admissions to hospitals in England (2008/9 – 2021/22) due to being 'bitten or struck by a dog' and comparison to the estimated population of England.

Year	**Admissions (W54)***	**Gender Male***	**Male %**	**Mean Age***	**Population (Year)**	**Estimated England Pop+**	**Admission % per Pop**	**Admissions per 100,000**
2008/09	5,221	2,862	55	36	2008	51,815,900	0.010	10.1
2009/10	5,837	3,076	53	37	2009	52,196,400	0.011	11.2
2010/11	6,005	3,235	54	37	2010	52,642,500	0.011	11.4
2011/12	6,580	3,502	53	37	2011	53,107,200	0.012	12.4
2012/13	6,317	3,236	51	37	2012	53,493,700	0.012	11.8
2013/14	6,836	3,468	51	38	2013	53,865,800	0.013	12.7
2014/15	7,332	3,673	50	39	2014	54,316,600	0.013	13.5
2015/16	7,673	3,705	48	40	2015	54,786,300	0.014	14.0
2016/17	7,461	3,644	49	40	2016	55,268,100	0.013	13.5
2017/18	8,014	3,798	47	42	2017	55,619,400	0.014	14.4
2018/19	8,507	4,090	48	41	2018	55,977,200	0.015	15.2
2019/20	8,859	4,152	47	42	2019	56,287,000	0.016	15.7
2020/21	7,386	3,594	49	40	2020	56,550,000	0.013	13.1
2021/22	8,758	4,141	47	42	2021	56,536,000	0.015	15.4

* Source: Admissions, gender, and mean age (NHS Digital).
+ Source: Estimated mid-year population in England (Office of National Statistics (ONS)).

To gather accurate data and information on dog bites, a consistent definition is required. However, dog bite definitions in research are often not provided. Even when they are, there are consistency issues: the definition varies from one item of research to another; the definition is subjective in its interpretation; the terminology used varies (e.g. play bite; nip) or the perceived intention of the dog may or may not be noted (Oxley e*t al*., 2019). For example, dog bites during play is included in some research (Cornelissen and Hopster, 2010), but excluded in others (Beck and Jones, 1985). Thus, comparisons between studies, especially those which include minor bites, are difficult (Oxley *et al*., 2019). More recently, Oxley *et al*. (2019) surveyed 484 dog bite victims and determined their agreement on what they would consider to be a dog bite from five predefined statements ranging from no contact to multiple bites causing puncture wounds. The majority (>80%) stated they would consider it a dog bite if it caused bruising or puncture(s) to the skin. Therefore Oxley *et al*. (2019) defined a dog bite as "*causing at least bruising or skin puncture and regardless of the perceived intention of the dog*". Therefore, we use this definition going forward when referring to a dog bite in the current research.

The anatomical location of bites differs, adults more frequently bitten on their extremities and lower arms and legs compared to young children who are more often bitten on the head, neck and face (Horisberger *et al*., 2004; Rosado *et al*., 2009; Chen *et al*., 2013; Piccart *et al.,* 2019; Hurst *et al*., 2020; Jakeman *et al*., 2020; Alberghina *et al.*, 2023). The difference in injury location can be attributed to potential factors such as a the head, neck and face of children being the closest distance to the dogs muzzle, children may also be less aware of safe distances and interact inappropriately with a dog e.g. hugging, kissing, pulling the dogs tail, interfering with a dog when it is sleeping or eating, and/or be more likely to misinterpret dog behaviour and emotions e.g. a dog showing its teeth and growling as the dog smiling (Love and Overall, 2001; Schalamon *et al*., 2006; Meints *et al*., 2010; Lakestani *et al*., 2014; Meints *et al*., 2018; Eretová *et al*., 2020). In contrast, adults may be more likely to be in charge of managing a dog such as restraining or walking a dog or splitting up two dogs fighting, or maybe more likely to use their hands when interacting with dogs, e.g. stroking or patting (Rosado *et al*., 2009; Oxley *et al*., 2019). It is also important to note that multiple human, dog and environmental factors, may also play a role in dog aggression and dog bite incidents such as the location and context of the bite, relationship between the victim and the dog.

1.5 Impacts of dog bites on human physical and psychological health

Dog bites can result in a physical injury varying from minor bruising or break to the skin, not requiring medical treatment (Westgarth *et al*., 2018), to severe injuries requiring emergency treatment, such as bone fractures or the loss of a limb or a finger requiring extensive surgery (Shields *et al*., 2009; Lee *et al*., 2019; Cook *et al*., 2020), or in rare cases death (Mora *et al*., 2018; Sarenbo *et al*., 2021; Tulloch *et al*., 2023). However, even relatively minor bites may not initially require medical attention, but secondary infections may result in the need for medical treatment (Piccart *et al*., 2019).

The impact of physical injuries due to dog bites can result in the need to take time off work which is likely to have a financial implication for the individuals and families involved (Overall and Love 2001; Langley, 2012; Owczarczak-Garstecka *et al*., 2019; Royal Mail, 2023). In some cases, an occupation may require frequent contact with dogs (such as delivery workers, kennel workers, veterinary staff) and individuals may no longer feel they can undertake the role due to the psychological or physiological impact of a bite incident (EFRA Committee, 2013; Owczarczak-Garstecka *et al*., 2019; Royal Mail, 2023).

Despite the majority of research focusing on physical injuries, there is some evidence to indicate that a dog bite incident can potentially impact an individual's psychological health. For example, Peters *et al*. (2004) found that of 22 dog bite victims under 16 years age, over half (55%; 12/22) reported symptoms indicative of PTSD (Post Traumatic Stress Disorder). Additionally, Anyfantakis *et al.* (2009) reported a case of a four year-old girl that was bitten by a dog resulting in mutism and symptoms indicating PTSD. In addition, Westgarth and Watkins (2015) also note that other psychological aspects, such as emotion, do affect victims of a dog bite incident including guilt, embarrassment and shame. However, it is important to note that there is a gap in research which focuses on the long-term and short-term psychological impacts of both human directed dog aggression and bite incidents to both children and adults (Watkins and Westgarth, 2017).

1.6 Impacts of dog bite incidents on dog welfare

Of the research to date, the impact dog bites has mainly focused on the human victim. However, limited research has explored the impact dog bite incidents have on the dog involved and their welfare. Oxley *et al*. (2018) recently surveyed self-identified dog bite victims in the UK and asked participants about what happened to the dog as a result of a bite incident. Over half (60%) of the 484 participants reported the incident result in no implication for the dog involved and of those that did report consequences for the dogs involved the three most reported were sought training/advice (11.3%), the dog was euthanised (8.0%) or rehomed (3.5%). Similarly, Fragoso *et al*. (2022) also conducted an online survey and identified 729 respondents that had been previously bitten by a dog in Portugal and the consequence for the dog involved. There were no implications for the dog in over half (58.3%) of cases and where there were implications for the dog the most common was 'punishment' (34.5%), training (3.5%), euthanasia (1.9%), relinquished/rehomed (1.4%) or seized by authorities (0.7%).

Dog bite incidents may also result in the breakdown of the human-dog bond or result in a change in management of the dog resulting in decreased welfare (e.g. reduced walking or off lead walking or being muzzled which may have an impact on a dog's natural behaviour). In severe cases where a dog has bitten a child or adult, the dog involved may be seized or relinquished regardless of the context in which the bite occurred. Given the dogs history it may be difficult to rehome and as a result spend a long period of time in dog kennels. Previous research has indicated the potential negative welfare impacts the kennel environment can have on dog welfare e.g. limited exercise, human-dog and dog-dog contact (Taylor and Mills, 2007; Polgár *et al*., 2019).

1.7 Public knowledge and interpretation of dog body language and methods of assessment used

As children are more likely to be hospitalised as a result of dog bites (Loder *et al.,* 2019), it is understandable that the majority of research focuses on understanding human perceptions and interpretation of aggressive dog body language has largely focused on children (Chapman *et al*., 2000; Spiegel *et al*., 2000; Wilson *et al*., 2003; Meints and De Keuster, 2009; Dixon *et al*., 2012; Lakestani *et al*., 2014; Shen *et al*., 2015; Shen *et al*., 2017; Meints *et al*., 2018). However, it is important to note that recent research has identified that dog bites to adults were the main reason for the increasing trend in hospital admissions due to dog bites in England (Tulloch *et al*., 2021). Furthermore, a range of dog bite prevention education and advice also promotes the active supervision of children by adults (The Blue Dog (Meints and De Keuster, 2009); Safe and Sound Scheme, n.d.; Dogs Trust, 2023). For example, the Dogs Trust have recently introduced advice for parents/caregivers including the 'three S's' (stay close, step in and separate) (Dogs Trust, 2023). This is especially important given previous research highlighting that parents often underestimate, lack knowledge and awareness about the potential risks and unsafe behaviours associated with child-dog interactions (Wilson *et al*., 2003; Reisner and Shofer, 2008; Arhant *et al*., 2016). Therefore, it is important to assess both child and adult knowledge of dog body language and emotions in order to successfully design and implement dog bite prevention education strategies.

To date there had been a range of methods used to explore human interpretation of fearful and aggressive dog body language and signals, which will be expanded on in coming chapters. Previous research has mainly used multiple photographs (Bloom and Friedman, 2013; Jalongo, 2018), short videos (Tami and Gallagher, 2009; Meyer *et al*., 2014; Lakestani *et al.,* 2014; Demirbas *et al.,* 2016; Meints *et al.,* 2018; Aldridge and Rose, 2019) or animations (Meints and De Keuster, 2009) of dogs displaying specific behaviours in an attempt to understand human interpretation of dog behaviour and emotions. However, this requires sourcing suitable videos and often includes various breeds, environments, video quality and viewpoints, potentially resulting in little standardisation. Although research to date using the current methods is likely to have been beneficial in furthering our understanding of this topic, further research is needed to explore novel methods which allow more realistic opportunities. New technologies may be used to allow researchers to simulate a real-life situation without the possibility of harm to either the dog or human. Virtual Reality (VR) (see section 1.9) may provide such an opportunity.

1.8 Dog bites and blame

To date, limited research has been conducted regarding the attributions of blame in dog bite incidents. Of the research conducted, it is evident that dog owners and victims are blamed rather than the dog involved. For example, Westgarth and Watkins (2015) conducted interviews with eight individuals that had reported being bitten in the last five years; four individuals required medical treatment as a result of the bite and the remaining four did not. None of the victims blamed the dog involved and the majority (6/8) blamed themselves for the bite with the remaining two victims blaming both themselves and the owner of the dog. Oxley *et al*. (2018) surveyed 484 self-identified dog bite victims in the UK and were asked who was to blame for the bite. The dog was only blamed in 12.7% of incidents, whereas the majority of victims either blamed themselves (44.6%) or the owner (39.9%).

It has been found that dogs may be treated differently to humans when it comes to assigning blame for dog bites. For example, Rajecki *et al*. (1998) found that a dog biting a child may be treated with more leniency, provided with more of an excuse and rated lower for blame and intent compared to a child biting a child. As a result, the authors suggest that owners may deem some of the dog bite incidents as being the result of external factors which are out of the dogs' control and therefore less likely to blame the dog involved (Rajecki *et al*., 1998). More recently, Owczarczak-Garstecka *et al*. (2018a) reviewed user comments associated with ten dog bite videos in different scenarios via the social media platform YouTube. The authors concluded that perceived blame for dog bites was most often assigned to the individual people involved (i.e. the victim, owner/handler or parent/caregiver) rather than the dog, as it was viewed that people had the ability to prevent a bite from occurring whereas dogs were perceived to not be responsible for their own behaviour. Therefore, undesirable dog behaviours, especially in the case of aggression, may often be seen as more the responsibility of the owner or person involved and less to do with the dog involved (Sanders *et al*., 1990; Sanders *et al*., 1994). However, it is important to note that biased and intense media reports of dog bites focusing on specific breeds have previously resulted in changes to legislation (e.g. breed specific legislation) and may influence the public's perception of specific high profile dog breeds (Podberscek, 1994; Kikuchi and Oxley, 2017). For example, Arluke *et al*. (2017) found that in the popular media and medical literature there was bias in the reporting and the blaming of specific stereotypical breeds (e.g. Pit Bull, German Shepherds) for dog bites often without sufficient supporting evidence.

1.9 What is virtual reality?

Although Virtual Reality (VR) is thought to be a relatively recent development, the first head mounted display (HMD) was developed by Ivan Sutherland in the 1960s allowing a user to view 3D objects within a computer-generated environment (Sutherland, 1968). For a detailed timeline of factors which have, contributed to the development of VR technology see Sherman and Craig (2018) and Whyte and Nikolić (2018).

'Virtual Reality' (VR), a term not made popular until the 1980's, is a broad and commonly used term that lacks a commonly agreed definition. Lanier (2017) provides fifty-one different definitions of VR (also see a critical review of VR definitions by Kardong-Edgren *et al*., 2019). For the purpose of this research VR is defined as: "*The use of computer graphics systems in combination with various display and inter-face devices to provide the effect of immersion in the interactive 3D computer-generated environment*" (Pan *et al*., 2006, p. 20).

More recently, Kardong-Edgren *et al*. (2019) stated that the term 'Virtual Reality' often differs between sources, lacks standardisation and therefore to clarify the definition of the term should include different levels of immersion (see Chapter 1.10) (low, medium and high). The latter criteria can be applied between non-VR (i.e., computer screen) and VR or to differentiate within VR (i.e. immersion between low-end and high-end HMDs). For example, low-cost HMDs, such as Google Cardboard (costs less than £15), may require the output device to be a mobile phone. Google Cardboard only allows the user to view a virtual environment through head movement alone (known as 3 degrees of freedom (3DoF) (i.e. pitch, yaw, and roll)) without bodily movement, only includes two forms of sensory feedback (visual and audio), and is used in a sitting position (Rubin, 2018). In contrast, medium or high HMDs allow the tracking of both body (forward/backwards, left/right, up/down) and head movement (pitch, yaw, roll) known as six degrees of freedom (6DoF) (Figure 1.3). They also provide multiple sensory feedback including haptics, visual, and audio and provide a higher resolution.

Therefore, the degree of immersion and presence (see section 1.10) is a key concept in VR and for sufficient presence 6DoF is required for adequate user experience in VR (Rubin, 2018).

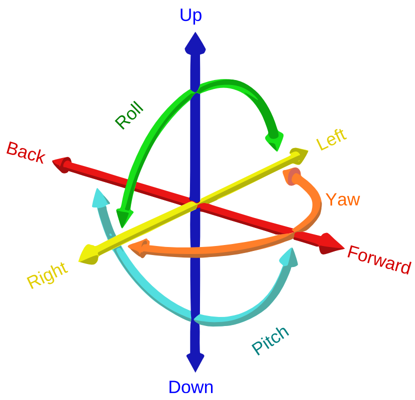


Figure 1.3 The six degrees of freedom (up/down, left/right, forward/back, roll, pitch, yaw) (Wikimedia commons, 2015; License CC-BY-SA).

To avoid confusion, other terms, such as augmented reality (AR), a sub section of mixed reality (MR), which contain aspects of both real and virtual contents, are often used in literature and are related to VR but include an overlay of virtual objects/images within a real environment by using specific technologies (i.e. mobile phone, tablets, or glasses). This allows the user to view both the real environment and virtual images together and can be demonstrated through the reality-virtuality continuum (Figure 1.4) (Milgram and Kishino, 1994; Kamphius *et al.*, 2014). Additionally, the term Extended Reality is used which refers to all forms of AR, VR and MR (Andrew *et al.*, 2019).

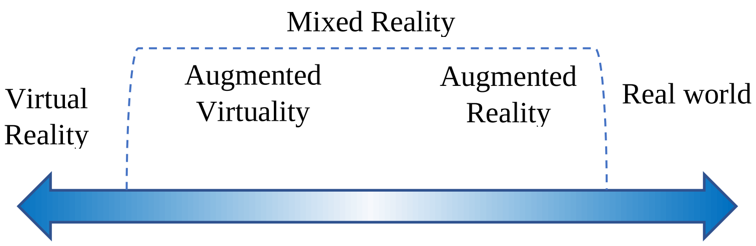


Figure 1.4 Milgram's (1994) reality-virtuality continuum (from left to right: an entirely virtual environment (virtual reality), an environment with mainly virtual and some real-world content (augmented virtuality), environment mainly real with some virtual content (augmented reality) and all content is based on the real environment (real world)).

The main two forms of visualisation in VR are through either HMDs or the CAVE (Cave Automated Virtual Environment) systems (also known as large screen display systems) (Sutherland and La Russa, 2017). Whilst CAVE systems allow multiple users to collaborate, they also have disadvantages. CAVE systems require multiple large high-cost screens and are not portable and not necessarily fully immersive (e.g. no screen on the ceiling, behind the user resulting in a break in presence) (Mestre, 2017). More recently, it has been questioned whether the CAVE system is required at all due to the recent developments and similar benefits which are offered by AR HMDs (de Vasconcelos *et al*., 2019).

1.10 Virtual reality head mounted displays (HMDs)

Currently, a range of HMDs are available ranging from low-end (mobile phone-based HMD (e.g., Google cardboard)), medium-end (all in one HMD (e.g. Oculus Quest and Quest 2)) and high-end (computer enabled via a power cable to the HMD (e.g. Oulus Rift s, HTC Vive/Vive Pro)) (PwC, 2018). Lower quality HMDs may potentially suffer from the 'screen door effect' (i.e., lines between pixels which can be seen) (Peddie, 2017). These include HMDs with a low resolution (<500 PPI) or where the output device is a mobile phone and/or require magnifying lenses (e.g. google cardboard). Higher end HMDs have better resolution (e.g., HTC Vive Pro has 615 PPI (Table 1.2)) and therefore are generally not affected by this phenomenon.

Advances in technology have made VR hardware and software cheaper (e.g. Slater (2018) states that a HMD (Oculus) alone cost $35,000 in the 1990s compared to the current Oculus Rift which can be purchased for less than $600). The latter is more compact and therefore accessible to a wide audience, including the public, this has also resulted in an increase in the research which has been conducted using VR. For example, a basic search of article titles using the term "Virtual Reality" on PubMed revealed a clear increase (1999 (63), 2009 (106) and 2019 (703)) in the number of published articles. Currently, there are a variety of HMDs available with varying technological capabilities (Table 1.2).

Table 1.2 High end commercial VR HMDs and their specifications in order of release.

HMD	Year of release	Resolution (per eye)	Refresh Frequency (Hz)	Field of Vision (degrees)	DOF	Standalone / Tethered
Oculus Rift	2012	1080 x 1200	90Hz	110	6DOF	Tethered
HTC Vive	2016	1080 x 1200	90Hz	110	6DOF	Tethered
Sony PlayStation VR	2016	960 x 1080	120Hz	100	6DOF	Tethered
Oculus Go	2018	1280 x 1440	72Hz	100	3DOF	Standalone
HTC Vive Pro	2018	1440 x 1600	90Hz	110	6DOF	Tethered
Oculus Rift S	2019	1280 x 1440	80Hz	110	6DOF	Tethered
Oculus Quest	2019	1600 x 1440	72Hz	110	6DOF	Standalone
HTC Vive Cosmos	2019	1440 x 1700	90Hz	110	6DOF	Tethered
HP Reverb	2019	2160 x 2160	90Hz	110	6DOF	Tethered

Pimax Vision 8K X	2019	3840 x 2160	75 or 90Hz	200	6DOF	Tethered
Valve Index	2019	1440 x1600	80–144Hz	120	6DOF	Tethered
Oculus Quest 2	2020	1832 x 1920	72Hz/120Hz*	110	6DOF	Standalone
HTC Vive Cosmos Elite	2020	1440 x 1700	90Hz	110	6DOF	Tethered
HP Reverb G2	2020	2160 x 2160	90Hz	114	6DOF	Tethered
HTC Vive Pro 2	2021	2448 x 2448	90Hz	120	6DOF	Tethered
HTC Vive Focus 3	2021	2448 x 2448	90Hz	120	6DOF	Standalone
Meta Quest Pro	2022	1800 x 1920	90Hz	106	6DOF	Standalone
Pico 4	2022	2160 x 2160	90Hz	105	6DOF	Standalone

*120Hz due to update

A key component VR is ‘head tracking’ (or position tracking) via the HMD and handsets as this allows the VR system to identify where the users head and hands are in the physical environment and the corresponding virtual environment (Bolter *et al*., 2021). Two main types of head tracking systems are used including i) inside-out (also known as ego motion tracking) which does not require external tracking devices (e.g., lighthouses/base stations)) as the tracking is inbuilt into the headset or ii) outside-in tracking (requires external tracking devices e.g. the HTC Vive requires two base stations, one at each corner of the area) (Gourlay and Held, 2017). However, the former has been noted to provide less accurate environment tracking whereas the latter has been noted to not be limited by external tracking device, require less equipment and setup time (Gourlay and Held, 2017; Monica and Aleotti, 2022).

1.11 Why use virtual reality?

Virtual reality enables the development of, and control over, a virtual environment and its contents. This is of great benefit from a research and education perspective as it enables the recreation and study of environments and scenarios that would otherwise be difficult or impossible to study in the real world without endangering participants or that are too complex (Pan and Hamilton, 2018). For example, VR has been used to assess the behaviours of both adult and child pedestrians. For example, Luo *et al*. (2020) was able to identify risky behaviours (i.e. not looking for traffic when crossing or running into the street) when children were crossing a virtual street. In the case where human directed dog aggression is being investigated, real-world research becomes ethically problematic due to the possibility of physical injury or psychological stress to the human and/or dog involved. Therefore, from a safety perspective VR is likely to be beneficial. See chapter 2 for a review of dog models used in VR and AR.

A key factor in the use of VR is the potential for study replication as VR applications can be shared and repeated regardless of the real-world environment and the VR environment remains independent (Pan and Hamilton, 2018). Additionally, VR can be conducted with a single person and does not need additional individuals to be part of the task set up as these can be represented virtually (e.g. a dog handler) (Pan and Hamilton, 2018). In the case of research being conducted on human-dog interactions in a real-world scenario, dogs would need to be sourced, and may vary in size, breed, sex and age. Furthermore, research and the general use of dogs (i.e. for education) may be limited to specific locations in which the test could be conducted as many locations do not allow pet dogs in buildings.

As previously stated, research exploring human behaviour and education in the presence of dogs displaying behaviour signals often use photographs, videos and animations (see section 1.7). Virtual reality may provide additional benefits compared to the latter more traditional formats as VR is often; immersive resulting in a person feeling like they are present in the virtual environment (i.e. 'being there'), tracking of the HMD and handsets allowing for real world movements to be synchronised with movements in the virtual environment allowing for different viewpoints, reduces or excludes external stimuli (e.g. noise) due to the enclosed HMD and VR can engage additional senses (e.g. via haptics) (Higuera-Trujillo *et al*., 2017; Yeo *et al*., 2020) (see sections 1.9, 1.10 and 1.12. for an overview of VR, HMDs, immersion and presence).

Prior to undertaking research in VR there are also potential drawbacks which need to be carefully considered. For example, to develop and run detailed virtual environments, sufficient high specification VR and computer hardware is needed which is costly. For example, if inadequate hardware is used this could result in a delay or lag (i.e. latency) between a user's real-world movement and the virtual movement experienced in VR and may affect immersivity and presence (see section 1.12) and cause side effects such as simulator sickness (see section 1.13) (Morel *et al*., 2015). Transferability from VR to the real world is less understood especially where human injury prevention and safety is concerned. This is especially the case as virtual environments and models, although these may be based on the real-world, are not real unlike other formats such as video footage (Yeo *et al*., 2020).

However, previous research has directly compared videos, 360 videos and computer-generated VR in multiple disciplines such as healthcare, education, training, and phobia treatment. For example, Yeo *et al*. (2022) compared a five-minute task involving the viewing a coral reef with fish in order to improve mood via a TV, 360 VR video via a HMD (allowed 3DOF (i.e. head rotation only)) and a computer-generated VR via HMD (allowed 6DOF (i.e. head rotation and physical movement around in the VR environment) and interact with fish via handsets). They found that presence, feeling connected to nature and positive mood was significantly higher in the computer-generated VR compared to 360 VR video (head rotation only) and TV. Previous research focusing on education also found that in 49 school children (aged 13 – 16 years of age) that undertook an educational field trip in VR (via an HMD) scored higher in presence, interest, enjoyment and retention of knowledge post-test compared to 53 children who watched a 2D video of the field trip. Regarding phobia treatment, a recent systematic review of nine studies found that VR exposure therapy is no less effective when compared to in vivo exposure therapy (Wechsler *et al.,* 2019). Similarly, when comparing the use of in vivo, VR and AR for the use of exposure therapy for small animal phobias (e.g. spiders and cockroaches) the authors found that the three methods were all similar in their effectiveness (i.e. reduction of fear and anxiety in a behavioural approach test) (Suso-ribera *et al.,* 2019). In the present research, as a starting point, we focus on the development of a virtual dog model and explore aspects of human behaviour in the presence of a virtual dog using VR and videos.

1.12 Immersion and presence

Immersion is regarded as a fundamental aspect in order to experience VR successfully and is often used with the definition of VR (see section 1.7). However, the term immersion is broad, used interchangeably and lacks a unified definition (Berkman and Akan, 2019). For clarity, here we use the term immersion to refer to the technological or objective factors which enables the user to become immersed e.g. tracking, degrees of freedom, HMD and resolution, refresh and frame rate (Cummings and Bailenson, 2016; Doerner *et al*., 2022, p. 17). Whereas an individual's psychological or mental subjective experience, particularly in VR, is more commonly referred to as 'Presence' (Doerner *et al*., 2022, p. 17). Both immersion and presence are linked as the technological capabilities of equipment providing the VR/VE is directly linked to a user's ability to become psychologically immersed (Cummings and Bailenson, 2016).

Presence is a subjective experience whereby a user who is psychologically immersed in a VE whilst being physically in the real world is described as "being there" (Doerner *et al*., 2022, p. 17; Witmer *et al.,* 2005). Like immersion the definition of presence is problematic and varies between studies (Felton and Jackson, 2022). Although in a recent review of presence, Felton and Jackson (2022) propose a unified definition of presence as "*The extent to which something (environment, person, object or any other stimulus) appears to exist in the same physical world as the observer*". It is important to note that presence occurs not only in VR but also via other avenues, such as playing computer games or watching videos. Therefore, here we refer to the term presence, which can be applied to both online videos and VR.

Several subjective scales are available to measure user presence in virtual environments. Recently a large-scale review by Gonçalves *et al*. (2021) identified that the two most commonly used presence questionnaires were the ‘Igroup Presence Questionnaire’ and the ‘Presence Questionnaire’. The ‘Igroup Presence Questionnaire’ consists of 14 items which cover three areas, spatial presence, involvement and experienced realism (Schubert *et al*., 2001). Whereas Witmer *et al*.’s (2005) ‘Presence Questionnaire’ consist of 29 items which cover four areas (involvement, sensory fidelity, adaption and immersion and interface quality).

1.13 Simulator sickness

Despite the popularity of VR in multidisciplinary research, training, education, and more frequently being used for entertainment and recreation (i.e., games), there is one aspect which has been identified a constant drawback, simulator sickness. The terms simulator sickness (SS), cybersickness, immersive sickness, VR sickness and virtually induced motion sickness are used in research interchangeably (Tanaka *et al*., 2004; Fox *et al*., 2009; Rebenitsch and Owen, 2016; Dennison and Krum, 2019). However, others have stated there are differences between specific terms such as SS and cybersickness. For example, Stanney *et al.* (1997) conducted a study and found that these terms differ, based on variances in symptoms, as cybersickness was generally associated with more disorientation symptoms and SS more often associated with more oculomotor symptoms. Either way, for clarity the research described in this thesis will use the term simulator sickness going forward and is defined by Bailenson (2018, p. 22) as “*an unpleasant feeling that occurs when there is a lag between what your body tells you you should be experiencing, and what you actually see*”. Bailenson is mainly referring to lag in this definition which is as a result of a low frame rate, or a delay based on the time it takes for the computer to process information and as a result a delay between when a user physically moves in reality and moves virtually.

Simulator sickness, a form of motion sickness, is often noted to be caused, and most commonly accepted, as a result of the Sensory Conflict Theory (Reason and Brand, 1975; LaViola, 2000), also known as Cue Conflict or Neural Mismatch Theory (Rangelova, 2018). The Sensory Conflict Theory refers to a conflict between the ‘visual and proprioception’ (awareness of position and movement of the body) and the ‘vestibular system’ and as stated by Dahlman *et al*. (2012) is due to a mismatch between “*what is perceived, what is not and what is expected*”. Other theories have been less commonly discussed concerning SS including postural instability (Riccio and Stoffregen, 1991) and poison theory (i.e., explained from an evolutionary perspective as if a user experiencing symptoms similar to that of being poisoned)

(Treisman, 1977; Mousavi *et al*., 2013). The three theories continue to be debated and all have research which supports them and aspects which are criticised (LaViola, 2000).

The extent of the problem (SS) continues to date, and potentially includes multiple symptoms (i.e., polysymptomatic) which can vary from unpleasant mild to severe physiological symptoms (e.g., dizziness, sweating, nausea, vomiting, eyestrain). Participation in virtual environments via a VR headset can potentially have consequences: even resulting in a user stopping the use of VR; a user withdrawing from a study that involves VR; injury to the user either during or after a session (Rebenitsch and Owen, 2016; Bailenson, 2018; Rangelova *et al*., 2018). Saredarkis *et al*. (2020) reviewed 46 VR articles using HMDs and reported the average withdrawal rate as a result of SS was 15.6%.

Simulator sickness, although a form of motion sickness, differs from the strict definition of motion sickness as the latter is thought to be mainly associated with gastrointestinal symptoms (i.e. nausea) whereas, as previously stated, SS also includes additional symptoms related to oculomotor (e.g. eye strain, blurred vision) or disorientation (e.g. dizziness, difficulty concentrating) caused by visual elements (Rangelova and Andre, 2018). Dennison *et al*. (2016) revealed that additional physiological indicators such as breathing and blinking rate, amongst others, accompanied SS and therefore could be used as further predicting measures.

The incidence of occurrence in individuals who show symptoms of SS varies between studies. For example, Cobb *et al*. (1999) found that 80% of 148 participants reported an increase in SS symptoms either during or after the VR experiment of which 5% needed to stop the task due to acute symptoms. However, with respect to studies look at SS in VR usage, comparisons between studies may be difficult for a number of reasons (Sharples *et al*., 2008). Firstly, it is important to highlight the developments in technology over recent years and the different types of VR head mounted display (HMD) technology used (see section 1.9 for a review of HMDs). Secondly, there are a variety of virtual environments. Thirdly, there are differences in associated factors (e.g., task type, timeframe, method of movement/navigation, etc) which makes the comparison of SS between studies difficult (Sharples *et al.*, 2008). Often the occurrence of SS may have referred to the use of older technology, for example, as stated above, Cobb *et al*. (1999) research is over 20 years old and thus used VR with lower technical capabilities (e.g., lower refresh and frame rate per second) than that currently available to date. Although recent research does indicate that the use of recent models of HMDs (e.g., Oculus Rift, HTC Vive) do continue to result in SS (Yildirim, 2020). A review by Dużmańska *et al*. (2018) found that the continuation of SS symptoms may vary between ten minutes to four hours post VR use.

The occurrence of SS has been noted to be influenced by a broad variety of factors such as the virtual reality system (type and quality of equipment (e.g. refresh rate, resolution, tracking accuracy)) (Saredakis *et al*., 2020), the physical and virtual environment (e.g. user movement (i.e. sitting (controller), standing (walking on the spot) or real-life movement) (LaViola, 2000; Lee *et al*., 2017)) and factors associated with the individual (e.g. age, gender, individual susceptibility, illness) (LaViola, 2000; Munafo *et al*., 2017)). Recently, Saredakis *et al*. (2020) conducted a systematic review and found that users experiencing SS involving HMDs were influenced by locomotion, motion within the virtual environment and exposure time. However, unlike Munafo *et al*., (2017), Saredakis *et al*. (2020) found that there was no difference between SS and gender. An individual's session exposure time to a virtual environment has been reported as an influential factor in SS (Dużmańska *et al*., 2018). Despite this, there is evidence to indicate that as an individual become more familiar with a virtual environment over time which results in lower levels of SS (assessed via simulator sickness questionnaire (SSQ)) being reported (Bailenson and Yee, 2006).

Guidance on the time spent within the virtual environment varies between sources. This is likely to vary based on the type of software and hardware which is being used. For example, Bailenson (2018) recommends twenty minutes of use and then having a break, whereas the more recently released Oculus Quest 2 health safety documentation states a break should be taken every 30 minutes whilst becoming accustomed to using the HMD (Oculus, n.d.).

As previously discussed, SS is potentially polysymptomatic involving multiple bodily systems and is, therefore, a multidimensional construct which is likely to be subjective. For this reason, Kennedy *et al*. (1993) developed the SSQ, originally based on the Pensacola Motion Sickness Questionnaire, and to date, it is the most popular tool available for the evaluation of SS (Gonçalves *et al*., 2021).

1.14 Research questions and objectives

This research in this thesis explores five main questions: 1) Can a virtual reality (VR) dog model (DAVE (Dog-Assisted Virtual Environment)) be used to assess people's behaviour in the presence of an aggressive dog and their interpretation of the dog behaviours? 2) What demographic or virtual model related factors impact human behaviour when viewing an aggressive virtual dog model? 3) What behaviours and emotions do participants observe when viewing a virtual dog model displaying aggressive behaviour? 4) Can a video of the virtual dog model be used to assess the perceived safest proximity to an aggressive dog and the interpretation of dog behaviours? 5) Can DAVE be used in the assessment of learning about dog behaviour and dog safety in veterinary students?.

To do this, five studies have been conducted using both VR and online surveys. Given the complex nature of human dog interactions, a range of human (e.g. demographics, dog related experience, personality) and dog-related factors (size, coat colour) have been considered which may be influential in human behaviour towards dogs. This information is likely to be of use and help further understand human-dog interactions and contribute to the development of new methods of dog bite prevention education.

Objective 1: Investigate if there is a difference in human behaviour and safest proximity to a virtual dog model using the Dog-Assisted Virtual Environment between a non-reactive and an aggressive scenario.

Objective 2: Use predetermined and validated measures to ascertain the occurrence of simulator sickness and the degree of presence and realism of participants using the Dog-Assisted Virtual Environment.

Objective 3: Explore if dog model characteristics (coat colour, size, audio) and different virtual environments affect participants' perceived safest proximity towards the dog model using videos of the dog model.

Objective 4: Explore if owner demographics, dog related experience and personality affect human behaviour towards the dog model using both virtual reality and videos of the dog model.

Objective 5: Identify participants' ability to interpret dog behaviour and the allocation of blame using the aggressive scenario virtual dog model in both virtual reality and/or online videos.

Objective 6: Investigate the use of a video of the Dog-Assisted Virtual Environment as an assessment tool for first-year veterinary students before and after a dog behaviour class and practical handling session.

The above objectives were addressed in the following chapters as follows:

Chapter four investigates the behaviour of 16 participants in the presence of a virtual aggressive and nonreactive dog through an exploration task in VR. Participants' interpretation of aggressive dog behaviour is recorded and their perceived presence and simulator sickness (Objectives 1, 2, 4 and 5).

Chapter five explores the use of an approach-stop task in VR to identify the proximity 18 participants get to a dog and the influence of a yellow and black coat colour. Participant personality and demographics are also recorded. This study also recorded the heart rate in ten participants (Objectives 1, 2, 3 and 4).

Chapter six uses an online survey of 559 participants who lived in the UK to explore the role of audio on the approach-stop distance towards nonreactive and aggressive using online videos (Objectives 1, 2, 3, 4 and 5).

Chapter seven uses an online international survey to explore if size (small, medium and large) coat colour (yellow and black) and different environments (indoor and outdoor) has an effect on approach stop distance towards a dog displaying aggressive behaviours through online video. In addition, participant view of the perceived emotion the dog is showing and who is to blame for the dog behaviour is also explored (Objectives 1, 3, 4 and 5).

Chapter eight is an online survey which assesses first year veterinary student approach-stop distance toward the dog, knowledge about the dog's behaviour and confidence in their ability. This is conducted pre and post a teaching and practical dog handling session, using a randomised controlled design (Objectives 1, 2, 5 and 6).

CHAPTER 2. A SYSTEMATIC SCOPING REVIEW OF HUMAN-DOG INTERACTIONS IN VIRTUAL AND AUGMENTED REALITY AND THE CURRENT USE OF DOG MODELS, MODEL REPRESENTATION, QUALITY AND EQUIPMENT USED

[***This chapter has been published as a journal paper***: Oxley, J. A., Santa, K., Meyer, G. and Westgarth, C. (2022). A systematic scoping review of human-dog interactions in virtual and augmented reality: the use of virtual dog models and immersive equipment. *Frontiers in Virtual Reality*, 12.]

2.1 Background

Over the past 30 years, pets have been replicated by technology including virtual (2D) and robotic pets. These can be either 'realistic' or 'unrealistic.' Realistic pets are based on the appearance and/or behaviour of a real animal, e.g. Nintendo dogs (a virtual pet dog); AIBO (Artificial intelligence robot, a robotic dog), and Lakaigo (a robotic dog imitating the locomotion of a real dog). Unrealistic pets do not fully resemble real-life animals but may have similar characteristics, e.g. Furby (a robotic pet); (Laureano-Cruces and Rodriguez-Garcia, 2012; Rativa *et al.*, 2019; Bylieva *et al*., 2020; Peng *et al.,* 2020). The traditional market for virtual pets, whether implemented as quickly as games or robots, is mainly children. Children use virtual pets for the purposes of: i) entertainment; ii) learning how to take care of a pet (e.g. walking, feeding, etc., where the pet deteriorates in the absence of care), without the cost associated with real pet ownership; iii) companionship (Luh *et al*., 2015). However, virtual dogs (e.g. Nintendo dogs) can stimulate emotion and emotional attachment in users (e.g. Weiss *et al.* (2009) found that children made an emotional attachment with a robotic dog, AIBO) (Laureano-Cruces and Rodriguez-Garcia, 2012; Bylievia *et al*., 2020), but invariably they do not offer the same level of companionship to that of a real pet might provide (Chesney and Lawson, 2007). Comparing social affordances between a stuffed dog and a virtual dog, the stuffed dog was associated with friendship and the virtual dog was associated with entertainment (Aguiar and Taylor, 2015). More recently, Lin *et al.* (2017) conducted a survey of 774 individuals who played games that included a virtual companion (e.g., Nintendo dogs) and found the main reason for playing was because the individual could not own a real pet (e.g. due to allergies) and virtual companions were deemed a form of emotional support.

In addition to entertainment, virtual dogs have a use in public health and education. Research has been undertaken into the use of virtual dogs for children as a means of increasing breakfast (Byrne *et al*., 2012) and fruit and vegetable consumption (Ahn *et al*., 2016) and promoting physical activity (Ruckenstein *et al*., 2010; Ahn *et al*., 2015; Hahn *et al*., 2020), improving attitudes and increasing empathy (Tsai and Kaufman, 2014), reducing obesity

(Johnsen *et al*., 2014) and promoting effort making behaviours in learning (Chen, 2011). More recently, virtual animals have also been incorporated into mobile gaming apps (e.g. Pokémon Go) and have been found to be beneficial for human physical and psychological health. For example, Kogan *et al*. (2017) found that Pokémon Go usage increased the time spent with family members, walking their own 'real' dog, and exercising, as well as reducing anxiety levels.

As a result of recent technological advances, increased availability and the significant reduction in cost of equipment, the use of Virtual Reality in research has increased (Slater, 2018). The term 'virtual reality' (VR) refers to a simulated three-dimensional environment in which a user can be psychologically immersed through VR or AR (Augmented Reality) technology (such as an HMD or CAVE, and interact with the environment, through visual, auditory and haptic feedback (Virtual Reality Society, 2017; Johnston, 2018). VR provides a range of benefits such as user immersion and presence in the environment, the ability to potentially interact with a virtual object (such as a pet), the ability to elicit an increased degree of emotion, and the viewing area is much greater compared to 2D formats and is often, but not always, controlled by natural user movement (Lin *et al*., 2017). However, the degree of immersion, presence, perceptions and interactions in VR may be influenced by a variety of factors such as equipment, user's knowledge and experience, virtual environment, model development and appearance/quality/realism (e.g. the 'Uncanny Valley' as previously seen using realistic and unrealistic images of cats and dogs) (Yamada *et al*., 2013; Lin *et al*., 2017; Schwind *et al*., 2018).

There has been development of VR and AR applications for public entertainment. For example, in the VR game 'The Lab – Postcards', released in 2016 by the Valve Corporation, a user can interact with a virtual robotic dog (fetch-bot) and the interaction includes haptic feedback upon contact with the dog and throwing a stick which the dog retrieves (Lin *et al*., 2017). More recently, as with Nintendo dogs in 2005, an AR mobile application dog 'Dex' has recently been developed where users can walk, feed, play and look after their pet dog (see Labrodex Studios, 2019).

More specifically, virtual animals may be of use in addressing public health outcomes directly related to contact with animals. For example, hospital admissions in England as a result of dog bites are increasing (Tulloch *et al*., 2021a) causing significant physical injury. Interventions to prevent these occurring are required. Dog bites can also result in ASD (acute stress disorder) or PTSD (post-traumatic stress disorder) (Peters *et al*. 2004; Ji *et al*., 2010). VR animals developed for research and treatment of human participants exist. For example, the use of VR and/or AR for animal phobias, in the form of exposure therapy, is well established and includes a range of species such as spiders (Miloff *et al*., 2016; Tardif *et al*., 2019), cockroaches (Botella *et al*., 2010), dogs (Farrell *et al*., 2021), cats (Yapan *et al*., 2023), multiple small animals (Quero *et al.*, 2014; Suso-Riber *et al*., 2019) and animals in general (zoophobia) (Suárez *et al*., 2017). Additionally, software companies also provide animals models for health care professionals for the treatment of various phobias (dogs, cats, snakes, spiders) (e.g. see InVirtuo (http://invirtuo.com/)).

The use of VR, in animal simulations has animal and human welfare implications. It may often be more ethical (i.e. no live animals used) and practical (i.e. one has control over a virtual stimuli/environment). In addition, it is a more affordable alternative to the use of live animals whilst allowing for repeated treatments (Farrell *et al*., 2021). Examples, include, animal-assisted therapy (Ratschen and Sheldon, 2019) (e.g. the Dolphin Swim Club https://thedolphinswimclub.com/), dog phobia treatments (Farrell *et al*., 2021) and animal dissections (Lalley *et al*., 2010).

Despite the latter benefits, to the authors knowledge, there has been no scoping review on the current use, efficacy, advantages and disadvantages of the use of dog models in VR and AR. Here we focus specifically on a scoping review of direct human interactions with VR and AR dog models and the consideration and representation of the models' physical appearance (i.e. breed) and behaviours displayed. The accurate representation of dog models and their behaviours is important, especially where they are used for injury prevention (e.g. education) and/or post-injury mental health treatment (e.g. phobia treatment).

Dog bites are often described as being 'unprovoked' (Love and Overall, 2001), however, this is often not the case as evidence indicates that dogs show a range of behaviours before a dog bite occurs indicating stress, ranging from subtle 'appeasement' signals (e.g. lip licking, yawning) that individuals may be less aware of to those that are more obvious (e.g. growling, showing teeth, barking) (Shepherd, 2009; Owczarczak-Garstecka *et al*., 2018). Therefore, the accurate representation of evidence-based dog behaviours is important from a public health viewpoint. Further, to ensure that the successful treatment of dog phobia occurs an individuals' understanding, and recognition of dog behaviour is important (e.g. when to and when not to approach a dog in the real world based on behavioural signals). Furthermore, in the context of dog bites and aggression, the public media is often negatively biased towards specific dog breeds (e.g., bull breeds) (Kikuchi and Oxley, 2017) and this may influence public opinion. Therefore, exploration of breeds chosen and their contexts in VR and AR is important to evaluate.

2.2 Aims

If effective use of VR animal models is to be applied to real-world situations, an evidence-based approach is needed. Therefore, this review aims to:

1) Explore the scope of the field in which VR/AR dog models have been used in research with the focus directly on human-dog interactions.
2) Describe the representation of virtual dog models (e.g. appearance/breed) and dogs behaviour including evidence-based development and fidelity.
3) Identify what equipment is used and if/how these differ between studies.
4) Describe the main findings of the research and measures used, both objective and subjective, to assess the human-dog interaction and other measures used in VR.

2.3 Method

This scoping review adhered to Preferred Reporting of Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and methodology (Moher *et al*., 2009).

2.3.1 Identification of relevant studies and search criteria

Literature from a 30-year period (1990 – September 2020) was reviewed due to the rise in the popularity of VR from the 1990's and the invention of CAVE in 1992 (Cruz-Neira *et al*., 1992). Data collection occurred on the 9th and 10th of October 2020.

Due to the multidisciplinary nature of research articles using VR and AR dog models, ten databases were searched, covering psychology (APA), veterinary science (CABI direct), medical and veterinary (Cochrane library, PubMed, Medline), technology, computing, and engineering (IEEE, ProQuest) fields, in addition to the large databases Scopus, Web of Science, and Google Scholar. In addition, to database searches, references from relevant articles were identified by reviewing these manually. The search terms were used to identify relevant articles using the article title, abstract and/or keywords (Table 2.1).

Table 2.1 Search terms used for title, abstract or keywords.

Search terms
("Virtual Reality" OR "Virtual Environment" OR VR OR "Mixed Reality" OR "Augmented Reality") AND ("Companion animal" OR "companion pet" OR "pet animal" OR pet OR pets OR dog OR dogs OR canine OR cynophobi*)

*Asterisk indicates plural terms (e.g., cynophobic or cynophobia)

Peer-reviewed journal articles and conference articles were included in the search findings but not editorials, commentaries, or reviews (Table 2.2). Conference articles were included due to the recent emergence of this area of research and several relevant conference articles specifically focusing on human interactions with a VR or AR dog model (e.g. Hnoohom and Nateeraitaiwa, 2017; Norouzi *et al*., 2019).

Table 2.2 Inclusion and exclusion criteria for literature search.

Category	Inclusion Criteria	Exclusion Criteria
Time Frame	The article was published from January 1990 to September 2020	Articles outside this time frame
Language	English articles only	Articles which are not written in English
Article Type	Peer reviewed journal articles Conference articles (including prototypes and research articles)	Reviews/discussion articles, review/discussion conference papers, abstracts only, editorials, letters, thesis/dissertation.
Equipment used	VR and AR HMDs (including smartphone HMDs (e,g. google cardboard), CAVE/Screen.	Mobile phones/tablets used on their own without an HMD.
Literature focus	All articles which include a VR representation of a live pet dog which displays behaviours and is the main focus of the article.	VR robotic dog models, anatomical models, 2D dog models, real dogs and/or non-dog animal models. Software/technical development with no VR usage.

2.3.2 Behavioural Dog Models

Articles included in the review are displayed in Figure 2.1. All articles involved dog models which displayed some form of behaviour and focused on direct interaction between the human and virtual dog. The first category of articles, for exclusion from this study, consisted of indirect VR dog model use; the dog model was not part of the main purpose of the study. Examples include, haptic forces used for rehabilitation through the use of simulated dog walking (Sorrento *et al*., 2018), used to facilitate the study (e.g. leads or assists the users to an area as part of a non-dog related study/task (e.g. Hung *et al*., 2018)) or study conditions (e.g., a red robot dog that barked to distract the user (Rewkowski *et al*., 2019)). Articles were excluded if they were in 2D due to the reported disadvantages when compared to 3D VR including reduced levels of presence, immersion, and spatial navigation success rates (Slobounov *et al*., 2015; Minns *et al*., 2018). Articles with the use of mobile phones were only included if they consisted of 3D VR/AR with an HMD as they are likely to provide a similar VR experience (e.g. stereoscopic vision, enclosed eyes). The second category, for inclusion in this study, was direct

VR dog model use; the dog model was a key part of the study with direct focus and involvement of, and/or interaction with, the dog model (e.g. phobia treatment) (Figure 2.1).

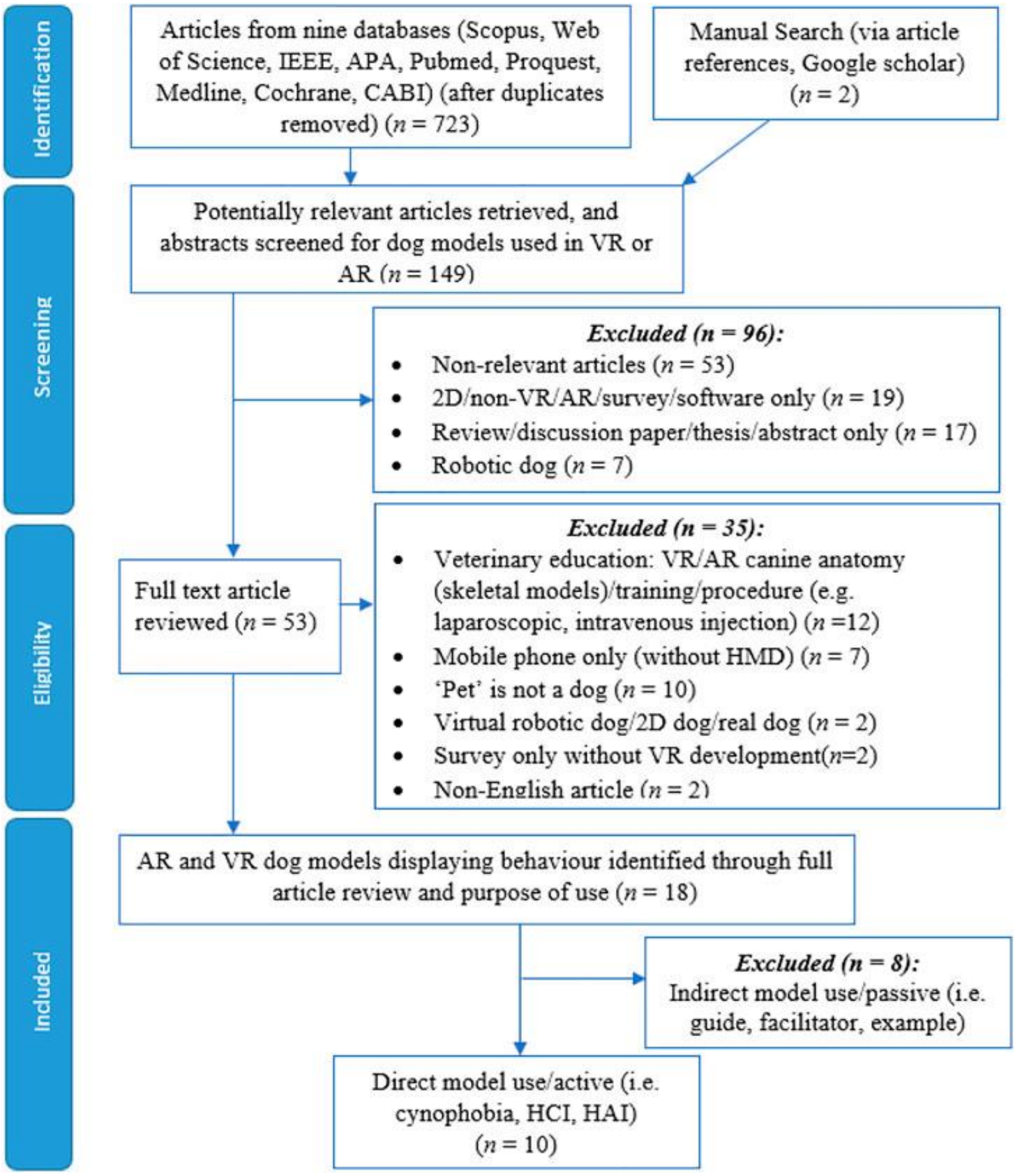


Figure 2.1 Workflow of the systematic scoping review.

2.4 Results

In total ten articles were found to directly research, or propose future research, human interactions with virtual dog models using a VR or AR set up. Despite the initial 30-year inclusion period, all articles were published from 2008 onwards. Nine articles included some form of results from participants [mean sample size = 13.2 (range: 6–32)]. One article described the development of VR animal models (including dogs) for future use to treat phobic participants but did not report research with participants (Maglaya *et al*., 2019).

2.4.1 Areas of research and measures

Nine out of the ten articles specifically focused on the topic of the development of a VR dog model to stimulate emotions or the proposed or actual treatment of individuals who were fearful or had a phobia of dogs (cynophobia) (6/9) or multiple animal phobias (i.e. zoophobia) which included cynophobia (3/9) (Table 2.3). One article targeted non-phobic individuals to investigate the proximity to and collision between an AR dog model and a human who was walking the dog.

Nine studies recorded some form of subjective measurement, with the most commonly used being the Subjective Units of Distress Scale, some form of presence measurement (e.g. Igroup questionnaire) and a subjective Behavioural Assessment Test. One study recorded biological/physiological measurements including skin conductance (Taffou *et al*., 2013). Another article briefly mentioned that measurements of heart rate, anxiety and sweating were recorded but no further details were provided (Saurez *et al*., 2017) (Table 2.3).

2.4.2 Main findings

Research articles mainly focused on the evocation of fear and the treatment of fear and phobias through VR dog models. It was evident that the dog models resulted in an increase in fear, distress, anxiety, and behavioural responses. Audio, where recorded, in the form of dog vocalisations (e.g. growling, barking) also appeared to increase fearfulness of the dog. Of those studies which specifically used the dog model as part of a dog fear or phobia treatment, these often result in reduced fear or phobia (Table 2.3). For example, in one article 75% of children were deemed as recovered one month after treatment (Farrell *et al*., 2021).

Table 2.3 Reviewed articles involving the direct use of VR or AR dog models, their sample size, subjective and objective measures, and main findings. (Asterisk * denotes research from the same research group).

Topic	AR/VR / Author / Article type	Aims	Study type / Sample / M/F	Subj. measures	Task & Obj. measures	Main findings
Cynophobia/fear of dogs	**VR** **Viaud-Delmon *et al.* (2008)*** **Conference paper**	"*The primary aim… is to determine the situations in which emotional reactions can be evoked in individuals who fear dogs. A secondary aim is to test the efficacy of progressive exposure… that can be manipulated in VR only (e.g.… dog behavioural control…)*" (p.2)	Preliminary / pilot study Fear of dogs screening survey (*n* = 75) (43M/32F VR study (*n* = 10) (M/F: n/a)	***[Proposed but not reported]*** • Fear of dogs questionnaire • Subjective Units of Distress (SUD) (Wolpe, 1973). • State Trait Anxiety Inventory (STAI) (Spielberger *et al*., 1983). • Cybersickness scale (Viaud-Delmon *et al*., 2000). • Presence Igroup scale (Schubert *et al*., 2001).	**Task:** Participants were required to locate targets by following a trajectory where dogs were present in a gradual exposure format. **Behavioural:** *"…count the behavioural reactions of the participants whenever they encounter a dog (step backward, freezing…)"* (p.4)	***[Descriptive results only]*** **Fear of dogs screening -** The Doberman was deemed the breed which evoked the most negative emotion. The size of the dog had an impact on participants emotional reaction. **VR study** - Participants focused on emotional stimuli (e.g. dog) rather than lighting conditions. Dog barking & growling resulted in high anxiety.
	VR **Taffou *et al*. (2012)*** **(*Note: Sub-sample of Taffou et al., 2013 results*)** **Book Chapter**	"*This study aims to precisely assess the impact of multi-sensory stimulation on fear reactions.*" (p.238)	Fear of dogs Screening survey (*n* = 110) (66M/44F) VR study (*n* = 11 took part but only 9 completed due to cybersickness) (M/F: n/a)	• State Trait Anxiety Inventory (STAI) (Spielberger *et al*., 1983). • Cybersickness survey (Viaud-delmon *et al*., 2000). • Igroup presence questionnaire (Schubert *et al*., 2001). • Subjective Units of Distress (SUD) (Wolpe, 1973).	**Task:** Training session & two Behavioural Assessment Tests (BAT) session involving a virtual dog showing different behaviours with a gradual increase (unimodal & static, unimodal & dynamic, audio-visual & static, audio-visual dynamic). Participants had to explore the area to find a green frog. **Behavioural:** BAT (score 0 – 14 (0 - participant did not want to enter the VR space; 14 - participant put their face against the virtual dog's face for >5 secs).	No sig. difference between two exposure sessions & both BAT scores. Sig. higher (p<0.01) SUD score in bimodal session compared to unimodal session. Two participants did not complete due to cybersickness.

Cynophobia/fear of dogs	**VR** **Suied *et al.* (2013)*** **Paper**	*"The primary aim of the current study is to identify the situations in which emotional reactions can be evoked in individuals who fear dogs. A secondary aim is to test the impact of features that can be manipulated in VR only"* (p.145)	Fear of dogs Screening survey (*n* = 115) VR study (*n* = 10) (4M/6F)	• State Trait Anxiety Inventory (STAI) (Spielberger *et al.*, 1983). • Cybersickness survey (Viaud-delmon *et al.*, 2000). • Igroup presence survey (Schubert *et al.*, 2001). • Subjective Units of Distress (SUD) before & after immersion (Wolpe, 1973). • Apprehension of virtual dog (3 point scale: 1 - not afraid, 2 - quite afraid; 3 - very afraid). • Fear of dogs questionnaire	**Task:** Participants were asked to explore the area to find a green frog which was visual and produced sound and found in the surroundings of the dogs. **Behavioural:** Behaviour ratings of the user in the presence of a virtual dog (scale 1 - 6 (1 - dog not noticed to 6 - dog noticed & flight or freeze))	Sig. higher (*p*<0.01) STAI scores between after VR exposure. Virtual dogs evoked a verbal & behavioural reactions (rating median score range 2 - 5 when exposed to 4 virtual dogs). Dog colour & audio influenced participants reaction. Most reactive to the growling dog with a dark coat. Presence (Igroup presence survey (score range 0-88)) noted as 'satisfactory' (mean score: 43.5; SD: 17.6). Presence scores positively correlated with apprehension of dogs & SUD scores. Cybersickness symptoms were reported.
	VR **Taffou *et al.* (2013)*** **Paper**	"*…our goal was to manipulate the presen-tation of auditory and visual aversive stimuli in order to investigate whether the multi-sensory presentation influences the conscious experience of fear.*" (p.348) "*Thus, we created a paradigm aiming at investigating the conscious experience of fear in the most appropriate and natural manner*" (p.350)	Fear of dogs screening survey (*n* = 225) Interview (*n* = 22) (12F /10M) VR study (high dog fearful (9) & no/low dog fearful participants (10) (n = 21 (9M/12F) but only 19 completed due to cybersickness).	• Diagnostic interview • Dog phobia questionnaire (Viaud-Delmon *et al*., 2008) • State Trait Anxiety Inventory (STAI) (Spielberger *et al.*, 1983). • Cybersickness survey (Viaud-delmon *et al*., 2000). • Igroup presence questionnaire (Schubert *et al.*, 2001). • Subjective Units of Distress (SUD) (Wolpe, 1973).	**Task:** Training session & 2 BAT sessions involving a virtual dog showing different behaviours with a gradual increase (unimodal & static, unimodal & dynamic, audio-visual & static, audio-visual dynamic, low visual contrast). Participants had to explore the area to find a green frog. **Biological:** Skin conductance (hands) level (pre & post immersion). **Behavioural:** BAT (score 0–14 (0 - participant does not want to enter the VR space; 14 -participant put their face against the virtual dog's face for >5 secs).	Sig. higher (P<0.01) SUD score in bimodal compared to unimodal session for both non dog & dog fearful groups. No sig. diff. between unimodal SUD between indoor & outdoor vEs. In the high dog fear group, sig. higher SUD ratings (p=0.008) were given for the dog growling than to the dog barking. No sig. diff. between growling & barking in the no/low fear group. Two participants did not complete due to cybersickness.

Cynophobia/Fear of dogs	**VR** **Hnoohom & Nateeraitaiwa (2017)** **Conference paper**	**"***In this paper we propose a virtual reality-based smartphone application for user exposure to face their animal fear phobia*."	Prototype & survey (*n* = 10) (5M/5F)	• Survey includes questions regarding age, gender, VR experience and fear of dogs. • Four-point Likert scale ("*Few, average, much, very much*"): Realism of application, 'dreadfulness' of the dogs in three levels, sound, animation, and distance between the player avatar and dogs.	**Task:** Participants explored three zones resembling a garden & house. Zone 1) A dog is asleep & wakes up if the user comes near the dog; 2) A dog in a cage faces & growls at avatar & finally attempts to attack user when near the dog; 3) Same as zone two but not in a cage & the dog runs, jumps & attacks the user. **Behavioural:** Not stated	***[Descriptive results only]*** A dog model and environment were developed. 50% of participants rated the free-standing dog in the back yard the most 'dreadful' followed by the dog in a cage and the dog in the house. 30% rated the following statement as 'much' and 60% 'average'. "*Hearing the dog sounds made us more fearful*"
	VR **Farrell *et al.* (2021)** **Paper**	*"...whether VR OST results in clinically significant improvement for children with a specific phobia of dogs using a controlled, multiple baseline case series design where participants are randomly assigned to 2-, 3- or 4-week baselines, followed by the VR OST and a 1 month follow-up."* (p.4)	Multiple Baseline (2, 3, 4 week) Case Series VR study (*n* = 8) (4M/4F; Children)	• Anxiety Disorders Interview Schedule: Parent (ADIS-P) (Silverman & Albano, 1996) • Fear Survey Schedule for Children–Revised Child Version (FSSC-R-C) (Ollendick, 1983). • Spence Children's Anxiety Scale Child & Parent (SCAS-C/P; Spence, 1998) • Subjective Units of Distress (SUD) (Wolpe, 1973). • Reality of VR stimuli 5-point scale (0 - not at all like real life; 4 - very real).	**Task:** Behavioural Assessment Tests (BAT) (pre & post VR & one month follow up): Enter through a door into a room, approach & stroke a real dog (on a lead with handler) for 20s. VR exposure task: Steps 1 – 10 (1 - dog on lead w/handler walk into opposite side of the room; 10 - dog in room off lead without handler). **Behavioural:** BAT (0 - didn't open the room to the door; 10 - completed the test) – pre-treatment, post treatment & one month follow up.	75% (6/8) children were deemed 'recovered' one-month after VR treatment. 87.5% (7/8) were able to complete the BAT (approaching & patting a real dog) task one-month post VR treatment. No significant decrease in anxiety or fear throughout the study for children.

Topic	AR/VR / Author / Article type	Aims	Study type/ Sample / M/F	Subj. measures	Task & Obj. measures	Main findings
Multiple phobias /Zoophobia (incl. Dogs)	**VR** **Suárez *et al.* (2017)** **Conference paper**	*"the objective of this project is to provide a reasonable alternative for treating various types of Zoophobias, using virtual reality*" (p.1)	Preliminary / pilot (*n* = 6) (M/F not stated)	• "*Laboratory tests were performed with the experimental group using virtual reality and traditional therapy with the control group. In each patient, five sessions and two levels of complexity were performed."* (p.5)	**Task:** Five sessions & two levels per person – No further detail provided. "*The clinical status of the patients involved in the tests had symptoms of high heart rate, numbness, excessive sweating and anxiety*" (p.5)	"*After the session of the fifth practiced patients treated with VR, although the symptoms did not disappear completely, an 80% decrease in anxiety, sweating and heart rate was observed in all cases; While patients in the control group treated with traditional therapy, they had a 35% reduction for the same symptoms.*" (p.6)
	Maglaya *et al.* (2019) **Paper (prototype)**	"*In this study and development, VR will be used as a tool to aid psychologist and psychiatrists in assessing and treating the different fear levels of patients*"(p1.39)	Prototype VR development for multiple animals (incl. dogs, spiders) & other phobias (claustrophobia)	• Not applicable - prototype	**Task:** Not applicable - prototype	Proposed usage for multiple animal phobias "C*ynophobia: The patient will be situated inside a house. Lower levels of experience will involve sounds coming from a dog. The next level will be a shadow of a dog outside the window. The next level will be a dog on a leash slowly getting closer to the patient until the patient can touch the dog*" (p.140)
	VR **Maskey *et al.* (2019)** **Paper**	"… *aims were to (1) evaluate treatment delivery feasi-bility, with fidelity, by therapists from two UK National Health Service (NHS) teams; (2) determine acceptability of outcome measures to young people and parents; (3) investigate responses to the VRE treatment; (4) monitor whether initial benefits from treatment persisted."* (p.1913)	Blind Randomised Control Trial (n = 32, Autistic children (8-14 years) – 3/16 had a phobia of dogs in the treatment group) (25M/7F)	• Social Communication Quest-ionnaire (SCQ) (Berument *et al.*, 1999) • ADIS-P (Silverman & Albano, 1996) • Vineland Adaptive Behaviour Scales (VABS) (Sparrow *et al.*, 2005). • Post-hoc Target behaviour ratings • FSSC-R-C (Ollendick, 1983) • Children's Assessment of Participation & Enjoyment (CAPE) (King *et al.*, 2007) • Confidence rating	**Task:** A single session of Cognitive Behaviour Therapy and four sessions, over two days, with the virtual reality (blue room) or control. Customed scenes designed based on an individual's phobia. The four sessions occurred in hierarchical order from lowest severity to most intense but only if low levels of anxiety were reported. CBT and relaxation methods were used during each VR session (such as challenging thoughts).	[Only three children had a phobia of dogs – but analysed entire sample with little reference to specific cases] In comparison to the control group, treatment groups had significantly improved on target behaviour ratings from baseline to 2 weeks (p = 0.021) and baseline to 6 weeks after the exposure session (p = 0.007).

HAI & Proxemics	**AR** **Norouzi *et al*. (2019)** **Conference paper**	"…*how the presence of the AR dog affected participants' proxemics, i.e. nonverbal behavior corresponding to one's physical space in response to other entities in that space, and locomotion behavior as well as their social bond with the AR dog"*	2x2 mixed-factorial design (*n* = 21 recruited but only 15 included in the analysis (University students)) (13M/8F)	• Co-presence questionnaire (Basdogan *et al*., 2000) • Godspeed questionnaire (Bartneck *et al*., 2009) • Perceived physicality questionnaire (Kim *et al*., 2017; Lee *et al*., 2018) • Affective attraction questionnaire (Herbst *et al*., 2003)	**Task:** Five phases (Dog personalisation, play with dog, witnessing a collision with the dog, walking with/without dog) **Behavioural:** Proxemics /locomotion (passing distance, walking speed, time looking at dog)	A sig. difference was found when alone or with a dog and speed of walking (slower when with the dog), passing distance of a person (larger when with a dog) and head rotations (more head rotations with a dog).

2.4.3 Equipment

Equipment varied from four studies using a AR/VR HMD (e.g. Oculus Rift) and five articles using a projection screen (single or multiple screens (e.g. CAVE/BARCO Ispace/Blue room)). Out of the nine articles where the user navigation/control method was stated, six used a hand controller (e.g. mouse, joystick, game controller, remote control), one article a therapist controlled the movement through a tablet, one article there was room scale movement for the user and one article it was unclear the if the user navigated or moved their head only (i.e. 3DOF or 6DOF) (Table 2.4).

2.4.4 Dog models

2.4.4.1 Breed, coat colour and behaviour

Seven articles stated the breed of the dog model used which included six studies using a single breed (German Shepherd, Beagle, Doberman (3), Rottweiler) and one study which included videos of multiple breeds (Cocker Spaniel, Labrador x Kelpie, Rottweiler x Border Collie, Cavoodle, Japanese Spitz). Where a single breed was used, in some cases different colours and textures of the models were included (Table 2.5). There was a lack of justification and/or scientific evidence for the dog behaviours displayed and were often predefined prior to purchase of the model. The number of behaviours displayed often varied between studies and limited detail about the behaviours was provided (Table 2.5).

2.4.4.2 Dog model quality

The quality of the virtual dog models in terms of polygon or vertices count was not mentioned in any article. In one case there was a web link to a pre-defined dog model which highlighted the number of polygons via an external website (Table 2.5). In one study investigating multiple phobias, the dog model was described in very little detail and therefore unlikely to be replicated in future research (Maskey *et al*., 2019). Another study used 360-degree video footage of real dogs in conjunction with a VR headset and separate assessments with the use of real dogs (Farrell *et al*., 2021).

Table 2.4 Equipment and navigation methods used in VR/AR research articles (Asterisk * denotes research from the same research group).

Topic	Author	Visualisation Equipment	Audio equipment	Haptics	Interaction modality
Cynophobia/fear of dogs	Viaud-Delmon *et al*. (2008)*	**Room/CAVE/Screen:** single screen "*300×225 cm² stereoscopic passive screen, corresponding to 90×74 degs at the viewing distance of 1.5 m, and are projected with two F2 SXGA+ Projection Design projectors. Participants wear polarized glasses.*" (p.3)	Sennheiser HD650 headphones	Not stated	Wireless mouse
	Taffou *et al*. (2012)*	**Room/CAVE/Screen:** As per Taffou *et al*. (2013)	Sennheiser HD650 headphones	Not stated	Wireless joystick
	Suied *et al*. (2013)*	**Room/CAVE/Screen:** As per Viaud-Delmon *et al*. (2008)	Sennheiser HD650 headphones	Not stated	3D mouse
	Taffou *et al*. (2013)*	**Room/CAVE/Screen:** "*The immersive space was a BARCO iSpace, a four-sided, retro-projected cube with Infitec stereoscopic viewing.... Participants wore polarized glasses*."	Sennheiser HD650 headphones	Not stated	Wireless joystick
	Hnoohom and Nateeraitaiwa (2017)	**HMD:** 3D Shinecon HMD glasses used with an android smartphone.	'Headphones' (separate to headset)	Not stated	Wireless remote control
	Farrell *et al*. (2021)	**HMD:** Oculus Rift **Other:** 360 videos - Fly 360 4K camera	Not stated	Not stated	Unclear if the subject walks causing the observed scene to shift or the subject does not walk but simply watches whilst standing or sitting a 360° video as the observed scene automatically shifts/changes.

Topic	Author	Visualisation Equipment	Audio equipment	Haptics	Interaction modality
Multiple phobias	Suárez *et al*. (2017)	**HMD:** Oculus Rift	Not stated	Not stated	Handheld game (Xbox) controller
	Maglaya *et al*. (2019)	N/A (proposed HTC and/or mobile phones HMD's)	N/A	N/A	N/A
	Maskey *et al*. (2019)	**Room/CAVE/Screen:** 'The Blue room' **"***interactive computer-generated audio-visual images projected onto the walls and ceilings of a 360 degree screened room. The room was 4m^3 and the participant and therapist sit side by side*"	Audio visual images – no further details provided.	Not stated	Therapist controlled using a tablet.
HAI & Proxemics	Norouzi *et al*. (2019)	**HMD:** *Microsoft AR Hololens* **Other***: Projection of images of the environment (office) onto walls.*	Audio via Microsoft AR HoloLens	Not stated	Room scale walking

Table 2.5 Dog model breed(s) used, justification, model quality (polygons/vertices), behaviours displayed and environment(s).

Topic	Article	Breed/s	Breed used in VR study	Justification of breed choice	Model quality	Dog behaviours/vocals	Environment/s
Cynophobia/fear of dogs	Viaud-Delmon *et al*. (2008)*	Built nine dog models: Alaskan Malamute, Boxer, Bull terrier Doberman, Great Dane, GSD, Miniature Pinscher Pit Bull Terrier, Staffordshire Bull Terrier	Doberman	Based on evaluation of nine breeds by ten participants who fear dogs and rated the Doberman the most negatively arousing.	Not stated	**Behaviours:** *"Several animations have been developed: running, walking, seating, jumping etc."* (p.5) **Vocals:** Growling and Barking	**Two outside environments:** A street with cars; a garden with trees and a house, tables & benches. **One internal environment:** Large dark hangar with different industrial machinery.
	Taffou *et al*. (2012)*	Breeds not stated (‘*several dogs were displayed’*)	Not stated	Not stated	Not stated	**Behaviours:** ”*They could be unimodal and static: auditory or visual alone (a dog barking from far or a dog lying down), unimodal and dynamic (looming and receding barking or visual dog standing up when the participant approaches), audiovisual and static (visual dog lying down and growling), audiovisual dynamic (visual dog standing up and growling when the participant approaches)*.” (p.239) **Vocals:** Barking and growling	A corridor was used for behavioural approach test. **Training scenario and 1st environment:** a garden with trees and a house, tables & benches. **2nd environment:** Large dark hangar with different machinery.

	Suied *et al.* (2013)	Built eight dog models: Alaskan malamute, Boxer, Doberman German Shepherd, Great Dane, Miniature pinscher, Pit Bull Terrier, Staffordshire Bull Terrier	Doberman (three coat colours brown, black and tan 'dark' and white/grey)	As per Viaud-Delmon *et al.* (2008)*	Not stated	**Behaviours: "***Several animations of the dog model have been developed: lying, walking, seating, and jumping. The dog model could growl and bark, and the experimenter could control the dog animations with keys*". (p.147) **Vocals:** Barking and growling	An open square with benches and a tree (with and without fog). A second garden is also connected to the first garden through a small alleyway in a residential area. The dog's location varies.
	Taffou *et al.* (2013)	Doberman (three coat colours brown, black and tan 'dark' and white/grey)	Doberman (three coat colours brown, black and tan 'dark' and white /grey)	Not stated	Not stated	**Behaviour:** Eight different levels were shown in an increasing manner. Behaviour included was similar to that of Taffou *et al*., (2012) (e.g. lying down, standing up, growling and barking) and included static, moving or following. **Vocals:** Growling and barking	As per Taffou *et al.* (2012)
	Hnoohom & Nateeraitaiwa (2017)	Unknown (human avatar purchased)	Rottweiler	"*This paper selected the model we use that suitable and realistic with the scene";* *"Rottweiler is fierce";* *" 26... animations can apply to this work."*	Not stated	**Behaviour:** 26 animations (not stated). The VR task consisted of three levels: 1. Dog sleeping in a living room and when participants approach it the dog sits up and starts panting. 2. Standing inside a cage in the back garden. When a user gets within close proximity the dog turns and growls at the user, if the user gets closer the dog will 'attack' and bark. 3. The dog is standing in the back garden and behaviours are the same as level 2. However, when a user is within closer proximity the dog runs at the user and eventually leaps and attacks the user. **Vocals:** Barking, growling, panting.	Residential area – 1) Living room of a house, 2) back garden in a cage and 3) outside the gate of the house.

	Farrell *et al*. (2020)	Video footage of six dog breeds: • Doberman • Cocker Spaniel • Labrador x Kelpie • Rottweiler x Border Collie • Cavoodle • Japanese Spitz	All six breeds used in VR video Post VR assessment with a real dog– dogs varied and no breeds were stated	"*Each dog was selected based on providing a variation of breeds and sizes to maximize variability.*"	4K 360 degree video viewed in a VR HMD	**Behaviours:** There were ten levels including: "*1 Dog and assistant walks into and sits on the opposite side of the room (on leash); 2 Subject moves closer to dog (on leash); 3 Subject moves closer to dog (on leash); 4 Subject moves directly next to dog (on leash); 5 Subject back to original side of room, assistant and dog standing up walking 1m forward (on leash); 6 Assistant and dog standing up walking 1m forward from previous position (on leash); 7 Assistant and dog standing up walking 1m forward from previous position (on leash); 8 Dog walking side to side and around camera (on leash); 9 Dog walking/running towards subject (off leash and assistant in room); 10 Dog without assistant in room and no leash"* (p7. Table 2) **Vocals:** Not stated.	'A large room' was used for the VR video treatment and post treatment. [limited information provided]
Multiple phobias	Suárez *et al*. (2017)	German Shepherd	German Shepherd	Pre-defined behaviour on purchase	"*Each of these models is really well made*"	**Behaviours:** "walk, run and sit" **Vocals:** Not stated	"*3D House model with three floors and furniture*"
	Maglaya *et al*. (2019)	Not stated	Not stated	Not stated	Not stated	**Behaviours:** Minimal detail ("*The Patient will be situated inside a house. Lower levels of the experience will involve sounds coming from a dog. The next level will be a shadow of the dog and gradually revealing a dog outside the window. The next level will be a dog on a leash slowly getting closer to the patient until the patient can touch the dog.*" (p.140))	"*The Patient will be situated inside a house.*"

	Maskey *et al*. (2019)	Not stated	Not stated	Not stated	Not stated	**Behaviours:** Minimal detail ("*Scenes are individualised, incorporating an exposure hierarchy related to the feared stimulus. For example, for dog phobia, adaptions include the dog's size, whether on or off a lead, barking, and proximity to the participant*.") (p.1916). **Vocals:** Barking	"*Scenes are individualised, incorporating an exposure hierarchy related to the feared stimulus. For example, for dog phobia, adaptions include the dog's size, whether on or off a lead, barking and proximity to the participant*." (p.1916).
HAI & proxemics	Norouzi *et al*. (2019)	Purchased [active link to external site]	Beagle (with four different coat textures)		808 tris (via link to model (p.3))	**Behaviours:** 42 pre-defined animations ("*including included eating, drinking, digging, walking, barking, sitting, resting, scratching, sniffing, and falling over*" (p.160). **Vocals:** Panting, barking and sniffing	"*a 3.89mx3.89m immersive CAVE-like environment with four projection walls and two doors facing each other. Regular office like images were projected onto the walls to make the participants feel like they were in an ordinary office room. We also prepared a 6.4m_2.13m walkway platform outside the interaction room, which we used to measure the part-icipants' walking behaviors with/without the dog*" (p.161).

2.5 Discussion

The aim of this review was to identify and assess research that directly involved the use of human interactions with dog models in VR and AR. To the authors knowledge this is the first scoping review specifically identifying and assessing human interactions with VR and AR dog models, model quality, behaviours displayed, and equipment used. Findings from this review highlight that although research using VR is well established, the development and use of VR and AR dog models for the purpose of human-dog interaction assessment is in its infancy. The use of VR dog models as a form of exposure therapy had positive effects. However, there was variation in the study sample size, VR equipment used and the behaviours displayed by the virtual dog, which tended to lack an evidence-based approach to the development of a canine model in relation to canine behaviour.

2.5.1 Equipment

There were several different VR HMD's and screen-based systems identified. Changes and advances in technology are inevitable. Furthermore, as technology improves other forms of HMD's become outdated and are no longer used which highlight the importance of stating technical specifications of all equipment used in research with VR models. This should include:

- **VR equipment (HMD/Screen/CAVE) specifications:** Navigation method, whether the VR HMD is 3DOF or 6DOF, HMD specifications (resolution, refresh rate, field of view, tethered or wireless), tracking (outside in or inside out), space and dimensions allocated, virtual hand movement or haptics, audio details including quality.
- **Computer/mobile phone equipment:** Name and model of computer/phone and technical specification (e.g., processor, graphics card, etc.).
- **Dog/Animal model:** Links to the sources of the model is not ideal and these may no longer work in future. Therefore, as much detail about the model is required such as: pre-purchased, developed in house or both, physical appearance and colour availability, polygons / vertices count, justification of model choice (e.g., cost, availability, prior research, expert feedback, etc.), all behaviours the model displays, justification of behaviours displayed (pre-defined when purchased, user feedback or canine behavioural expert feedback, etc.). In the case where there are multiple virtual animals used a separate appendix with all the details about the model specifications and sources should be provided. Ideally, images of the model would be provided.

- **Virtual environment:** The virtual environment is likely to impact human perceptions and behaviour and therefore any information about the environment used and justification of the environment is needed. Ideally, images of the virtual environment would be provided.

Alongside visual and audio feedback, haptic feedback in VR is important as it can enhance user immersion as it allows simulated physical interaction, and feedback, between a user and virtual or a combination of real and virtual objects within the virtual environment (Wang *et al.*, 2019). For example, Carlin *et al*. (1997) conducted a case study of an individual with a spider phobia and found that touching a real toy spider, whilst viewing a VR spider, provoked a strong emotional response. In the present review, no articles indicated that they used haptic feedback as part of the VR setup. This could be due to the type of studies that were conducted as the majority focused on the treatment of phobia and therefore the contact with a dog may be unlikely. In contrast, the use of haptics may be of use in a dog phobia context especially for patients who are gradually exposed and become comfortable with the presence of dogs eventually coming into 'contact' with the dog. The use of bespoke VR setups and varying navigation methods (e.g. mouse/joystick) by individual laboratories may have also played a role in the lack of haptic feedback used as separate development may have been needed. Having said this, the use of realistic haptic feedback in VR is complex and commercial VR controllers are limited to various basic forms of vibrations (Wang *et al*., 2019; Yin *et al*., 2021). Further research exploring the use of basic and more complex forms of haptic feedback (see review by Yin *et al*. (2020) for the current and future use of haptics in AR and VR) in human-dog interaction studies in AR/VR would be beneficial, especially in dog phobia and educational research. In the present review only one article used AR. More research is needed on the use of AR dog models as it provides increased ecological validity compared to VR and interaction with a user's own hands rather than virtual hands (Suso-Ribera *et al*., 2019).

2.5.2 Research studies

The majority of articles focused on the assessment and treatment of humans with a fear or phobia of dogs or animal related phobias. For example, Farrell *et al*. (2021) found that the majority of participants (75%) were deemed to have recovered one month after a one-session treatment, but the sample was small (n = 8). This technology could be beneficial in future clinical real-world applications. Recent hospital data indicates that NHS waiting times in England are an important public concern (The Kings Fund, 2021). There has also been a significant increase in demand for mental health services which has been exacerbated by the COVID-19 Pandemic (NHS Providers, 2021). In addition, the rate of hospital attendance due to dog bites has reported to have increased during COVID-19 lockdowns, likely due to the increased contact between humans and dogs (Dixon and Mistry, 2020). This could result in an increased rate of dog bite victims seeking mental health advice and treatment (such as for PTSD or ASD). However, mental health interventions such as exposure therapy is deemed a non-urgent treatment. Therefore, further research into the role of AR and VR technology which could assist mental health practitioners or even replace the involvement by professionals is needed.

Exposure therapy could be an opportune moment for the education of individuals about appropriate and inappropriate behaviour in the presence of dogs and general dog behaviour. Yet only a single paper mentioned, although briefly, that the researchers incorporated education about dog behaviour and safe interactions with a real dog (Farrell *et al*., 2021, p. 7). This highlights the potential for future research using VR and AR dog models as a form of educational intervention, either stand alone or alongside phobia treatment, for both children and adults, regarding appropriate behaviour around dogs and recognition of specific dog behavioral signals. Further exploration is needed into the impact that experiences with AR and VR dog models and associated educational applications have on the potential for participant behaviour change, as previously Schwebel *et al*. (2012) noted that dog bite prevention education in the form of online software may increase knowledge but does not result in behaviour change.

Often VR dog models are developed for an individual or multiple studies by the same organisation/research group and therefore there is little systematic re-use of dog models. Having different dog simulations makes comparisons difficult as each simulation may have different effects on human users, depending on how accurate the model's appearance and behaviour is. Similar issues have previously been highlighted in research involving virtual human avatars (Mountford *et al*., 2016). Further, little reference to the quality of the model (e.g. high or low polygons) was provided. Judging the quality of dog models is important due to the potential impact it has on a user's behaviour towards and interpretation of the dog. Previous research has highlighted that the impact of model quality and design (i.e. anthropomorphic features, naturalness, stylisation) could relate to the perceived realism of virtual animals (Schwind *et al*., 2018). For example, Schwind *et al*. (2018) note that if a virtual animals appearance deviates from its natural appearance (e.g. human facial expressions), or movement, then this can result in negative perceptions (e.g. eerie sensation/uncanny valley) of the virtual animals and may have the potential to affect interactions with them. In contrast one study, used a VR HMD (Oculus Rift) to view 360 videos of real dogs with positive results (Farrell *et al.,* 2021). Initial this method appears to overcome issues associated with the need to design accurate and realistic models. However, this format of VR has several practical limitations. For example, firstly, interactions with dogs in the video is not possible; secondly, initial video footage is required with various dog breeds, behaviours, space and permission to film the footage is required. Thirdly, additional ethical approval is needed for both the use of animals, especially where a dog is displaying aggressive behaviours, and human participants (Swobodzinski *et al*., 2020).

2.5.3 Dog breed

Several articles chose specific breeds such as Rottweilers or Dobermans (Viaud-Delmon, 2008; Hnoohom and Nateeraraitaiwa, 2017). In some cases, breed choice was justified, for example, Viaud-Delmon (2008) conducted the screening of nine different breeds, and based on ten participants, found that the Doberman was the animated dog model which provoked the most negative emotional response. However, the latter study did not state if participants had any previous experience with dogs or were involved with a dog related incident such as a bite. Further research would be useful to ascertain the difference between individual perception based on limited or no experience of dogs and those who are phobic of specific breeds due to a dog related incident.

Furthermore, other research does not appear to justify the choice of breed or chooses a breed based on likely biased perceptions of the breed; for example, Hnoohom and Nateeraraitaiwa (2017) used a VR dog model based on a Rottweiler breed and refers to the dog as a "*fierce dog*". Similarly, an online company advertising the treatment for the fear of dogs through VR also states, "*One of the most commonly feared dogs, Rottweiler, often considered dangerous*" (Psious, 2018). Similar inflammatory language (e.g. "ferocious" and "vicious") has been previously reported for Rottweilers and German Shepherds in medical literature (Arluke *et al*., 2018, p. 216).

Choice of specific breeds could have been influenced by external factors such as the news media which often focus on specific breeds (Kikuchi and Oxley, 2017) or breeds, such as Rottweilers, German Shepherds and Dobermans, frequently used as guard and police dogs (Podberscek, 1994; Meade, 2006). A recent survey of veterinarians in the US regarded the Rottweiler and German Shepherd as breeds which poses a high risk of biting and evoke a negative emotional response if an unfamiliar adult dog, which was off the lead, ran up to them

(Kogan *et al*., 2019). Although it is likely that some breeds may be perceived as more aggressive or fearful than others, it is important to highlight that all dogs have the potential to bite and can be due to multiple factors such as management, health status, genetics, and environment (including human and dog behaviour) (Haug, 2008). The role of dog model physical characteristics and the impact it has on human perception and behaviour is an area that requires further research, for example the effects of skull (brachycephalic, mesocephalic or dolichocephalic) and ear shape, tail length, coat colour and type, size (toy, small, large, giant) and weight (underweight or overweight).

2.5.4 Coat colour

The coat colour of the dogs was briefly discussed. Suied *et al*. (2013) found that participants were more fearful of the dark-coloured dog in comparison to the white or brown. However, given the same Doberman model was used, the reaction of participants could have been in relation to the most realistic dog model in terms of both breed and natural colour, as Dobermans are stereotypically known and associated in roles and the media with black coats colours and less often brown or not at all with white coats. Further research would be useful into the impact that coat colour has on human behaviour and participants perceptions; especially as black dog syndrome (also known as big black dog syndrome) appears to be frequently mentioned online despite there being little evidence to support this phenomenon (Woodward *et al*., 2012; Sinski *et al*., 2016). In previous research, breed specific differences and size have been found to be more influential factors than the coat colour of dogs (Woodward *et al*., 2012; Sinski *et al*., 2016). From a research perspective, VR is a useful tool in this respect as size and colour can be controlled and changed with relative ease, whereas multiple similar-looking dogs would be required in real life scenarios to test these variables.

2.5.5 Dog behaviours

The dog models used in this review appeared to display generic behaviour with limited evidence of behaviours being based on canine behavioural science research or expert feedback. It was evident that behaviours were frequently predefined based on models that were purchased. This could be due to the type of research that the dog models were being used for (i.e. dog phobias) and therefore it was perceived that a dog model which displays basic behaviours such as walking, sitting, barking, jumping was required. Alternatively, models that can be purchased with predefined behaviours can be preferable as less time is needed for development. However, accurate behaviour representation is important to consider, especially in the case of dog phobic participants. The display of subtle (e.g. growling, barking) and more intense (e.g. running towards, lunging or attacking (Hnoohom and Nateeraitaiwa, 2017)) behaviours towards participants is likely to be required for realistic treatment but also may cause significant stress and needs careful consideration in this context.

Realistic behaviours can be included in a form of exposure therapy and range from relaxed, play to fear and agonistic behaviours. It is important to note that dog behaviour can be complex and could be easily misinterpreted by an untrained individual. For example, appeasement signals (also known as calming signals) may include behaviours such as lip licking, yawning, and paw raises, indicating stress and discomfort which are often misinterpreted (Shepherd, 2009) and were not included in the reviewed articles. Similarly, theories about dog behaviours and their meaning can vary such as in the case of dominance of dogs towards humans (Westgarth *et al*., 2016). This highlights the importance of collaboration between animal behaviour experts and VR/AR developers. Often this type of collaboration appears to be lacking presumably due to the need for large amount of animation and technical development of models or the reliance on predefined models.

Finally, the importance of messaging also needs consideration, even if hypothetical, within the virtual environment especially regarding the treatment and management of animals. For example, Hnoohom and Nateeraraitaiwa (2017) display a virtual dog within a cage which, if in reality, it would be considered a serious welfare concern in many countries.

2.6 Conclusion

In conclusion, this review highlights the current limited use of dog models in VR and AR. The small number of reviewed articles generally were also limited by small samples sizes and the results need to be interpreted with caution. This review also only included English articles. Despite this there was some evidence to indicate that the use of VR to treat dog phobias is effective and holds much potential, especially including the assessment of participants physiological parameters. Of the studies found, there is a lack of emphasis placed on the dog model's behaviour, breed and quality. Future developments and research need to consider appearance (e.g. breed and unbiased basis for this), canine behaviour (based on up-to-date evidence-based research and canine behavioural expert review) and quality of dog models. We also recommend that the detail of the dog model is reported including the sources or development of the model, quality (i.e. polygons/tris/vertices), and behaviours displayed. Future collaboration between canine behavioural experts and VR and AR developers would be beneficial for an accurate and realistic representation of dogs in VR.

CHAPTER 3. DOG-ASSISTED VIRTUAL ENVIRONMENT (DAVE)

[**Sections of this chapter have been published as a journal paper:** Oxley, J. A., Meyer, G., Cant, I., Bellantuono, G. M., Butcher, M., Levers, A. and Westgarth, C. (2022). A pilot study investigating human behaviour towards DAVE (Dog-Assisted Virtual Environment) and interpretation of non-reactive and aggressive behaviours during a virtual reality exploration task. *PloS one*, *17*, e0274329]

3.1 Model development and peer review

The dog model (Dog-Assisted Virtual Environment (DAVE)) was purchased without animation and was a detailed model consisting of polygons 28,498 (VEC, Pers comms). The 3D model was rigged, which allowed for the development of animations of the model (Figure 3.1).

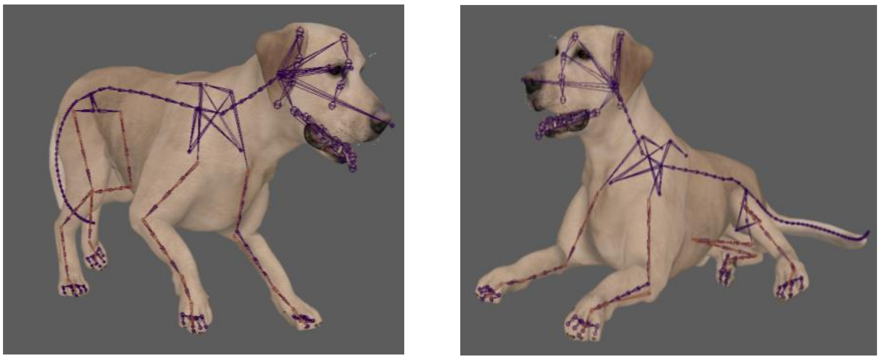


Figure 3.1 Rigged dog model (Virtual Engineering Centre).

Initial behaviours developed for the virtual dog model were based on features of the Canine Ladder of Aggression model that it was felt could be modelled feasibly by the virtual reality development team. To assist model behaviour development examples of specific behaviours (e.g. lip lick, yawning, paw raise, showing teeth growling, lunging and snapping) seen in the CLA were identified through YouTube videos by the author and a canine behaviour expert (Prof. Carri Westgarth) (see links to videos in Appendix 3.1). Modelling and animations were developed using Cinema 4D, Autodesk Maya and Unity.

In a pilot version of the VR environment, all behaviours were reviewed by four behavioural experts to ensure they represented the behaviours as based on their expertise and described in the CLA model and associated context (i.e. a corner of a room/area) (Figure 3.2). A range of feedback was provided including that the speed of breathing, blinking and lip licking was too fast, the ear position needed to move back when the dog was growling, and the legs needed to be less splayed when the dog was crouched down and growling during levels 7 & 8.

All feedback was incorporated into the model and experts reviewed the final model and provided the following statement in support of the model:

"We are unanimously agreed that proof of principle is clearly demonstrated. We can see a range of potential for the development of practical applications in a variety of contexts to improve animal welfare and reduce risk to both people and dogs. Potential environments include both professional development and public education. Examples of the former would be vet student training, people who work in animal-assisted therapy. The immersive level of the system is excellent and choice of Labrador perfect as people assume them to be friendly. Virtual reality allows for the first time to put people in a situation that is realistic and tease out the different behavioural signals people are recognising and responding to. By knowing what people are attending to, we can develop a more intelligent education system".

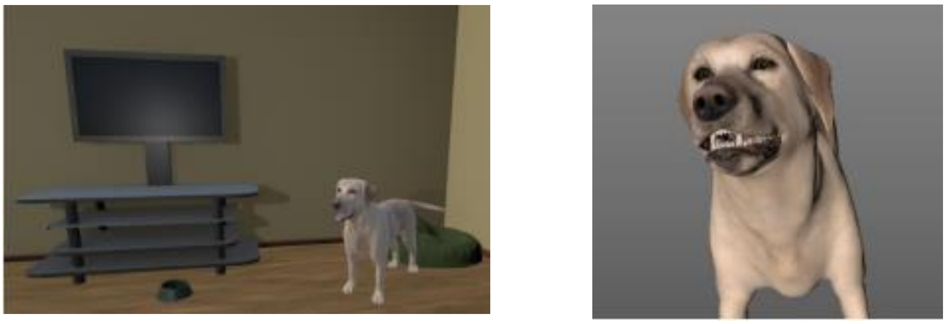


Figure 3.2 First DAVE model as a proof of concept (Virtual Engineering Centre). Dog and indoor environment (left) and dog showing teeth and growling (right).

3.2 Final dog model application

3.2.1 Main menu

At the start of the DAVE application a main menu (Figure 3.3) appears which requires a unique user ID before the user can proceed and allows for the customisation of the dog model; including the dog's colour (216 solid colours are available), size (30% - 300%), animation mode (static, non-reactive and aggressive) and (none [blank white space], indoor [living room], outdoor [a park]). The setup of the VR environment is based on real-world (or room-scale) walking/movement, regarded as the 'gold standard' for immersion in VR (Vasser and Aru, 2020).

Figure 3.3 Main menu of the DAVE application

3.2.2 Dog model

The dog model (polygons: 29,498; vertices: 29,117) (Figure 3.4) used in DAVE application is based on a Labrador due to the common view of the breed being a family dog, the most popular breed in the UK and the three coat colours including yellow, black and brown/liver/chocolate (Whitwam 2015; Kennel Club, 2022; Kennel Club, no date).

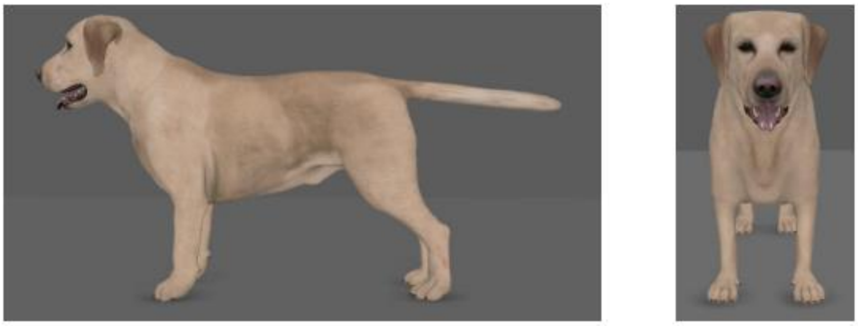


Figure 3.4 Lateral and anterior view of the dog model (Virtual Engineering Centre).

3.2.3 Apparatus

An HTC VIVE Pro HMD (Head Mounted Display) (resolution: 1440x1600 pixels per eye; refresh rate: 90hz; field of view 110° (VIVE, n.d.)) was used with two HTC VIVE Pro handsets (HTC Corporation, Taiwan). The HMD was connected to MSI GT76 Titan 17.3-inch 4k ultra-HD laptop (Intel Core i9 9900k processor). Both head and hand position coordinates were tracked via SteamVR 2.0 base stations and output through custom Unity software (Unity Technologies, San Francisco), programmed by VEC, Daresbury, UK.

3.2.4 Virtual dog model scenarios

The two virtual environments used resembled a domestic indoor living room of a house during the evening (i.e., dark outside, lights on) and an outdoor park during the day (Figure 3.5). Two different dog behavioural scenarios were used including:

- **Non-reactive scenario:** The non-reactive dog model displays a range of neutral behaviours that change over time (irrespective of the participant's movement or location) as shown in Figure 3.6a.
- **Aggressive scenario:** The aggressive behaviours are based on the CLA model (Shepherd, 2009) and are dictated by a participant's distance from the dog and speed of approach (i.e. behaviours are split into 10 levels (0 – 9) (Table 3.1 and Figure 3.6b) and will display in order (1, 5, 6, 7, 8, 9) if the approach is <0.3m/s per level. If the speed of approach is >0.3 m/s the user will skip levels (e.g., level 1 – 6, 1- 7 or 1 – 8). (Also see a video of the dog model here: https://tinyurl.com/JOxleyPhDDigital)

Figure 3.5 The virtual indoor living room (left) and outdoor park (right) environment.

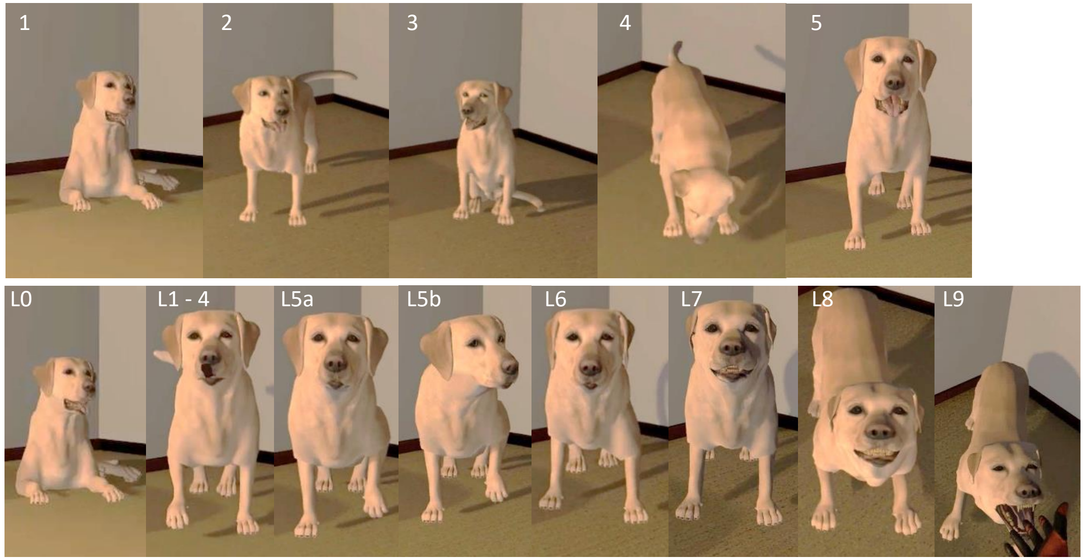


Figure 3.6 a) Behaviours in the non-reactive scenario; (1) lying down, (2) standing, looking left and right with tail wagging, (3) sitting with mouth open with relaxed tail, (4) Sniffing ground and (5) Step forward with left paw. b) Behaviours in the aggressive scenario at different levels (L); (L0) lying down, (L1-4) lip lick and yawn with increasing frequency, (L5a) paw raise, (L5b) paw raise and head turn. (L6) walking backwards, (L7) crouched with ears back, tail tucked underneath with some teeth showing (L8) crouched, growling, and showing teeth and (L9) Lunge/bite.

Table 3.1 Levels of aggression and behaviours the dog model (based on the Canine Ladder of Aggression model (Shepherd, 2009)).

Direction of participant	Level on approach	Dist.	Dog Behaviours	Level on retreat	Direction of participant
	0	5.0m	Lying down, not looking at the user, head turns left and right, mouth opening and closing (every 15 seconds).	**0**[+]	
	If moving at >0.3m/s will skip level until <0.3m/s. **1***	4.0m	Head follows the player. Stands and looks around with mouth open. No action movement by the user will trigger different behaviours e.g. sniffing ground. Occurrence of lip licking and yawning increases when moving closer.	**1**[+]	
	2[#]		After 15 seconds the dog starts to look at the user more often and mouth closes.	**2**[+]	
	3[#]		After 5 seconds sits down and head turns.	**3**	
	4[#]		After 10 seconds. Head remains turned, eyes dilate, eyes look and fix on user.	**4**	
	5	3.0m	Paw raise and head turned with dog looking from the side ‘whale eye’.	**5**	
	6	2.2m	Dog looks straight at the user, ears back and the dog walks backwards.	**6**	
	7	1.7m	Ears move back, tail tucked underneath the body, slightly crouched body posture. Jaws clenched dog growls without fully showing teeth.	**7**	
	8	1.0	Increased degree of crouched body posture, increased blink rate, jaws clenched with teeth showing. Growling vocalisations. Barks intermittently.	**8**	
	9	0.5	Lunge and snap at the user hand or head (closest device). Handsets vibrate indicating a ‘bite’ (level 8-9 repeats until the user backs away).	**9**	

* *Grey arrows indicate levels that respondents skip depending on the speed of approach by the participant.*
\# *For levels 2, 3, and 4 participants needed to stay still for ≥15 seconds, otherwise these levels are skipped.*
\+ *Once level 5 onwards has been triggered the earlier stages (0-2) will not be able to be shown again.*

Note: The specific order of behaviours displayed at each level are based on an attempt to deal with a perceived threat and avoid conflict and harm (Shepherd, 2009). The signals at lower levels of the ladder represent conflict defusing signals (see Levels 1 and 5), if a threat continues this is followed by conflict avoiding signals (see Levels 6 and 7) and finally if a threat is imminent then conflict escalating signals are displayed (see Levels 8 and 9) (Meints *et al*., 2018).

APPENDICES TO CHAPTER 3

Appendix 3.1 Videos of specific dog behaviours shown in the Canine Ladder of Aggression used for virtual dog model development.

Behaviours displayed	Time in video	Link to video
Growl with eye contact, yawn (stress) and stare/freeze.	0 - 8s	https://www.youtube.com/watch?v=Vy0WbT7wGZk&feature=youtu.be
Ear position, various growling, lunging and snapping.	17s – 1min 25s	https://www.youtube.com/watch?v=9ihXq_WwiWM&t=12s
Growling, snarling and lip licking.	0 - 50s	https://www.youtube.com/watch?v=TfZYLw4leQo
Side eye (whale eye), growling and snarling.	0 - 1min 50s	https://www.youtube.com/watch?v=nw7c1DjJipI
Lip licking and yawning.	0 - 1min 19s	https://www.youtube.com/watch?v=8DHLxKDDcXw
Lunge, snap, side eye (whale eye)	0 - 30s	https://www.youtube.com/watch?v=2JJG9W2-_aI
Paw raise	8min 29s, 8min 35s and 8min 54s	https://www.youtube.com/watch?v=t4N2XvnY7Mo
Ear position, growling, snarling, showing teeth	Ear position 18s, 21s, 40s, muzzle/nose wrinkling, snarling/ baring teeth and staring 21s and 40s.	https://www.youtube.com/watch?v=BUq7YBMxHc4
Ear and eye position whilst staring and growling	3min 19s - 3min 40s	https://www.youtube.com/watch?v=h9kpt_LAxmE

CHAPTER 4. A PILOT STUDY INVESTIGATING HUMAN BEHAVIOUR TOWARDS DAVE (DOG-ASSISTED VIRTUAL ENVIRONMENT) AND INTERPRETATION OF NON-REACTIVE AND AGGRESSIVE BEHAVIOURS DURING A VIRTUAL REALITY EXPLORATION TASK

[This chapter has been published as a journal paper: Oxley, J. A., Meyer, G., Cant, I., Bellantuono, G. M., Butcher, M., Levers, A. and Westgarth, C. (2022). A pilot study investigating human behaviour towards DAVE (Dog-Assisted Virtual Environment) and interpretation of non-reactive and aggressive behaviours during a virtual reality exploration task. *PloS one*, *17*, e0274329.]

4.1 Introduction

As discussed in Chapter 1, one of the negative consequences of human-dog interaction is dog bites. To prevent dog bite and reduce the impact on potential victims, owners, dogs, and local authorities we must first understand two contributing factors: 1) the ability of people to recognise and interpret dog behaviour signals; 2) the behaviour of people directly before dog bites occur. Current research generally explores human behaviour that occurs before a dog bite through a variety of methods such as questionnaires (Oxley *et al*., 2018), interviews (Westgarth and Watkins, 2015), police reports (Reese and Vertalka, 2020), online videos (Owczarczak-Garstecka *et al*., 2018) and newspaper reports (Kikuchi and Oxley, 2017). These methods have limitations, for example, questionnaires, interviews, police reports and newspapers often rely on victims or eyewitness recall and detail of the incident (i.e., recall bias).

To date, several studies have evaluated dog bite education interventions through either the use a live dog, photographs, animations or videos. For example, Chapman *et al*. (2000) evaluated children's (7-8 years) behaviour one week after an educational lesson about safe behaviour around dogs in comparison to a control group using a live therapy dog tied to a tree. They found that children who took part in the lesson were more cautious when approaching the dog compared to the control group (also see Schwebel *et al*., 2012). Although the latter maybe a useful method to identify the effectiveness of dog bite prevention education, there are multiple aspects to consider such as the requirement for a trained therapy dog and qualified handler to be available, ethical (i.e. impact on dog welfare or accidental injury) and practical concern (e.g. cost, staff) (Wilson *et al*., 2003). Previous studies have also evaluated educational interventions of human behavior around dogs through photographs. For example, Wilson *et al*. (2003) explored the effectiveness of a dog bite prevention educational intervention in children through the assessment of ten photographs, displaying seven high risk (e.g. a dog sleeping) and three low risk situations (e.g. a dog sitting next to its owner), pre and post intervention. The educational intervention (Delta Dog Safe) used puppets and photographs. The study found that children who undertook the intervention were more likely to identify high risk situations through photographs post intervention compared to pre intervention. However, photographs are static images that may be less realistic, provide little context to an overall situation (e.g. the behaviour(s) occurring before and after the captured behaviour) and therefore may be less effective as an assessment and/or intervention tool than when compared to animations or videos (Meints, 2017).

Meints and De Keuster (2009) used The Blue Dog computer program which was provided to children for a 2-week period which involved interactive animated stories depicting child-dog interaction in different scenarios. An assessment section was also included in order to evaluate children (3 – 6 years) with or without parents about safe behaviour and interactions with dogs. The study found that there was an increase in the recognition of safety knowledge (i.e. recognition of high-risk situations with dogs (e.g. a sleeping dog)) post program use across all age groups. Additional research using The Blue Dog program has reported similar findings (e.g. improvement of safety knowledge, more cautious behaviour) in children with an unfamiliar dog (Schwebel *et al*., 2012; Morrongiello *et al*., 2013), but no change was reported in parent behaviour towards supervised children (Morrongiello *et al*., 2013).

Several studies have used videos in dog bite prevention educational interventions either as part of a multiple formats (e.g. videos, workbook, role play) (Spiegel *et al*., 2000) or videos alone (e.g. testimonial educational video) (Shen *et al*., 2016). However, a review by Shen *et al*. (2017) highlighted that research conducted involving dog bite education found that, although photographs and videos were often effective methods of education, the focus of the interventions was on the avoidance or knowledge of risky or dangerous situations in the presence of dogs and not the actual human behavior around dogs or the correct/incorrect identification and interpretation of dog behavioural signals (e.g. during fear or stress). To address this, Meints *et al*. (2018) conducted research involving the impact of a teaching session on the correct recognition and interpretation of dog behavioural signals indicated distress, based on the CLA, for children and adults. Children and adults interpretation was assessed directly before and after, and six and twelve months following the teaching session (Meints *et al*., 2018). The teaching session was found to be effective for the recognition of conflict escalating signals as both children and adults improved their knowledge in comparison to the pre-test session but also retained knowledge about correct interpretation of these signals over the entire period of the study. Although younger children were less accurate at correct signal recognition and the subtle signals (i.e. conflict defusing signals) were the least the recognised by both children and adults (Meints *et al*., 2018). Furthermore, videos have also been used when assessing ability to interpretation dog body language, without an intervention, and emotions by children and adults through short videos (Lakestani *et al*., 2014; Demibras *et al*., 2016; Aldridge and Rose, 2019). However, videos may vary in length, quality (both visual and auditory) and lack control over the context or situation of the aggression, and these studies do not investigate actual behaviour around dogs. Despite the effective use of the latter formats, further consideration and exploration is needed to enable the assessment of human behaviour around dogs in a more interactive, immersive and controlled environment. To date little research has been conducted on actual human behaviour around an aggressive dog, via direct observations, most likely due to difficulties from an ethical (e.g. dog and human welfare) and context-specific (i.e. lab setting) perspectives (Bálint *et al*., 2017).

Virtual reality is a broad term but generally refers to an avenue that enables a user to become psychologically immersed in and interact (via technology) with, an artificial computer-generated 3D virtual environment (Brey, 2008). The benefit of this technology is that firstly the environment and its contents (e.g. a dog) can be controlled and modified as needed, and, secondly, the virtual environment, contents and tasks are physically safe (Omaki *et al*., 2017). To date, a range of research has used VR to assess challenging virtual scenarios/tasks, such as fire evacuations and pedestrian behaviour and safety during a road crossing, whilst the participant is within a realistic, but risk-free environment (Schwebel *et al*., 2008; Morrongiello *et al*., 2015; Omaki *et al*., 2017). VR also allows for users' behaviour to be monitored and tracked along with physiological responses (e.g. heart rate, skin conductance, etc.). VR has been frequently used in the psychological treatment of phobias including animal phobias (e.g. a fear of dogs (cynophobia) (see Chapter 2; Viaud-Delmon *et al*., 2008; Taffou *et al*., 2012; Suied *et al*., 2013) and Spiders (Armas and Andaluz, 2018; Miloff *et al*., 2019). More recently, an AR dog has been developed to assess user awareness, proximity, locomotion whilst walking a virtual dog (Norouzi *et al*., 2019). To our knowledge, no research has used VR in the assessment of non-phobic human behaviour for the purposes of understanding human behaviour towards aggressive dogs (see Chapter 2).

Here we present a VR application containing a realistic dog model and environment (known as DAVE, developed by Virtual Engineering Centre, University of Liverpool, Daresbury, UK) using a widely cited theoretical framework of dog behaviours, the CLA model (Shepherd, 2009), and assisted with input from canine behavioural experts (see Chapter 3)

The purpose of this pilot study was to assess the methodology, feasibility, and procedures, of an exploration task within the VR DAVE. This study aimed to evaluate the methods for i) tracking human approach and avoidance towards both a non-reactive and aggressive dog model using an exploration task, ii) comparing individuals measures of presence (i.e. the experience of being in a virtual world) within a virtual environment between a non-reactive and aggressive model; iii) assessment of participant recognition and understanding of the signs of behaviours based on the CLA.

4.2 Method

4.2.1 Participants

4.2.1.1 Recruitment

Students were recruited (Figure 4.1) through an online survey hosted by the survey software JISC, distributed through university departmental newsletters, posters (displayed throughout the university) and the university's Experiment Participation Recruitment system. Participant inclusion criteria included i) normal or corrected vision (contact lenses/glasses), ii) did not have epilepsy, iii) currently a student at the University of Liverpool, iv) not a veterinary or bio-veterinary science student, v) not scared/fearful of most dogs or have a phobia of dogs and vi) do not feel anxious around most dogs. For respondents who met these criteria information was then collected about demographics, dog-related experience and contact information. Participants were then invited to the study and randomly allocated, using Excel's 'RAND' function, to one of two groups, initially consisting of ten participants per group, each starting with a different scenario first (non-reactive or aggressive) as follows.

- **Group one (hereafter referred to as 'NA')**: Non-reactive scenario first and Aggressive scenario second.
- **Group two (hereafter referred to as 'AN'):** Aggressive scenario first and Non-reactive scenario second.

4.2.1.2 Sample size and demographics

As this was the first study using this virtual reality model the required sample size was calculated using a priori power analysis conducted in G*Power software (Faul *et al.*, 2007). To detect a medium effect size (0.50) (Cohen, 1988) between matched pairs assuming normal distribution, a one-tailed t-test with an α-level of 0.05 and statistical power of 0.80, a sample size of 28 participants was required. Therefore, 32 participants were initially enrolled in the study and 30 met the inclusion criteria. Nine participants did not respond to an initial and follow up request to take part in a practical session (Figure 4.1). Of the twenty-one students that were recruited, sixteen students took part in the practical session between February and March 2020 (Figure 4.1).

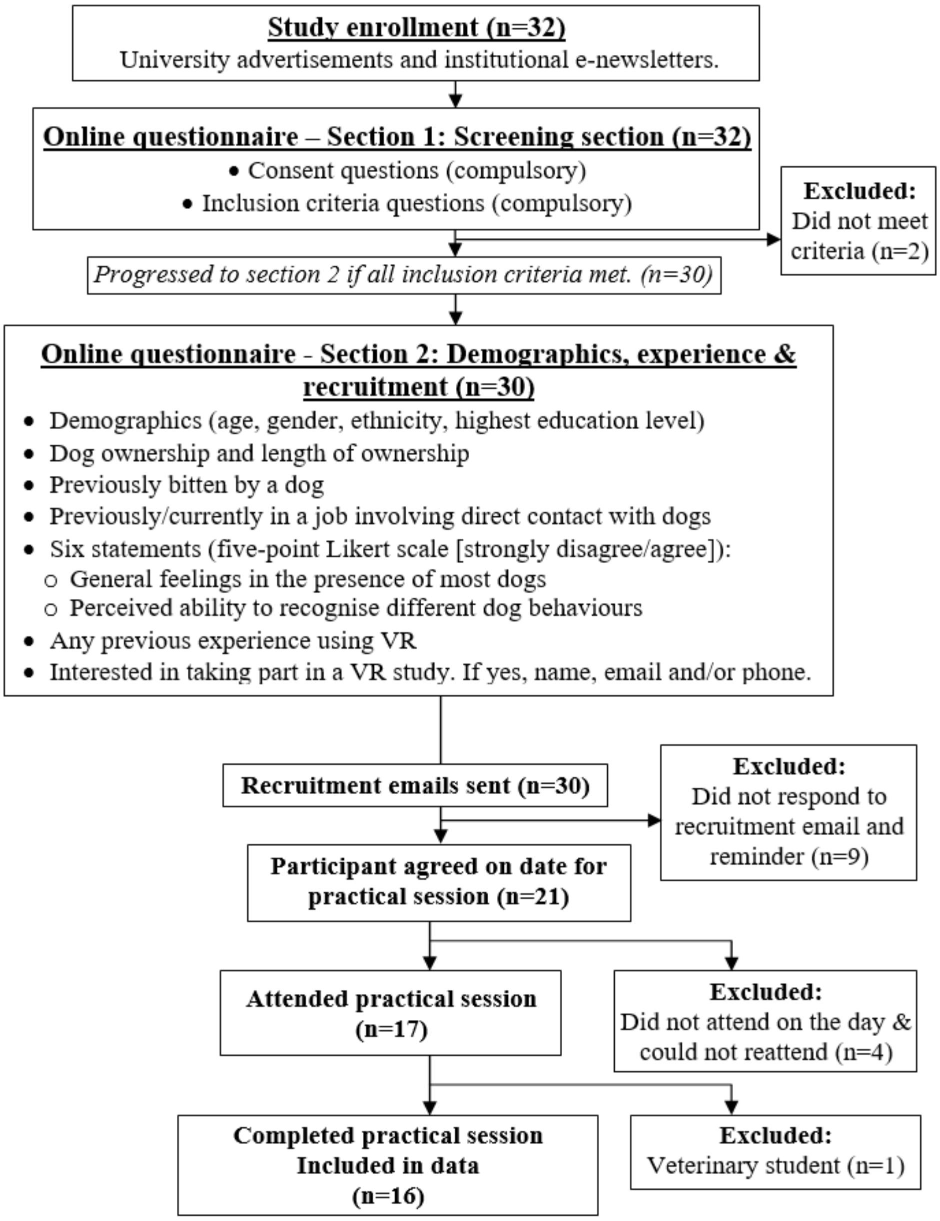


Figure 4.1 Pilot study screening and recruitment process.

Participants included undergraduate and postgraduate students from the University of Liverpool and were between 18-35 years of age (M = 25.19; SD = 5.78 years). Most were female (12/16) and educated to first degree level or higher (9/16), higher diploma (2/16) or to A/AS level (AS level) (5/16). Only three participants had been previously bitten by a dog (Table 4.1)

Table 4.1 Participant demographics and dog related questions.

Variable	n	%
Gender		
Male	4	25.0
Female	12	75.0
Ethnicity		
White	14	87.5
Asian/Asian British	2	12.5
Highest level of education*		
A/AS level	5	31.3
Diploma in higher education	2	12.5
First degree level qualification	3	18.8
University higher degree (e.g., MSc)	6	37.5
Current or previous dog ownership		
Yes, previously but not currently	8	50.0
Yes, currently	2	12.5
No	6	37.5
Length of dog ownership (n = 10)		
≥ 9 years	8	80.0
≥ 7 years but < 9 years	2	20.0
Previously bitten by a dog		
Yes	3	18.8
No	13	81.3
Job involving contact with dogs		
Yes	2	12.5
No	14	87.5
**Total percentage is 100.1% due to rounding to one DP.*		

Over half (62.5%; 10/16) of participants either had previously or currently owned dog(s), for seven years or longer. The majority (>80%) indicated that they were comfortable (i.e., enjoyed (87.5%; 14/16), felt relaxed (81.3%; 13/16) and were not cautious (81.3%; 13/16)) in the presence of most dogs and more than 80% felt that they could recognise when a dog is showing aggressive (93.8%; 15/16), fearful (81.3%; 13/16) or relaxed (93.8%; 15/16) behaviours (Appendix 4.2).

4.2.2 Ethics

The study was approved by the University of Liverpool Health and Life Sciences Research Ethics Committee (ref.: 5929) and conducted in compliance with the Declaration of Helsinki. All participants gave consent to take part in both the recruitment survey and at the start of the practical sessions. At the end of the practical sessions' participants were given a debrief about the purpose of the study, their behaviour towards the dog and the behaviours of the dog were discussed in the relation to the CLA.

4.2.3. Task procedure and data collection

4.2.3.1 Task procedure

Upon arrival at the practical task, all participants were asked to read an information sheet explaining the purpose of the study and data storage, read and sign a consent form and complete a simulator sickness questionnaire (SSQ) (Kennedy *et al*., 1993). The SSQ was reviewed by the instructor before the start of the task to ensure participants were not already experiencing moderate or severe symptoms (e.g., dizziness).

Participants were introduced to the VR equipment and informed that virtual boundaries of the action area are signalled and were instructed not to go beyond this boundary for safety reasons. The total task area was 6x2x7m (84m^3) in size. Participants were asked to stand in a 30x30cm marked area with their heels against the wall. At the start of each task, the participant was directly opposite the dog, 4.6 metres from the dog's nose (Figure 4.2). The VR headset was adjusted (i.e. interpupillary distance) to fit everyone to ensure a clear image and they were given two VR controllers. The instruction to "*explore the area*" once the environment appeared was given and the VR application was started by the instructor once the participant was wearing the headset comfortably. At the start of each practical participants had been informed they could stop at any point by either taking their headset off or saying "*stop*".

A period of five minutes was allocated to each task. After each task participants were asked to complete a post-task survey which included open and closed-ended questions about their perceived meaning of different dog behaviours (Appendix 4.1), a presence (Witmer *et al*., 2005) and a SSQ (Kennedy *et al*., 1993). In total, participants were asked to complete the SSQ on three separate occasions, once before the start of the first task and once after each task. (see surveys here: https://tinyurl.com/JOxleyPhDDigital).

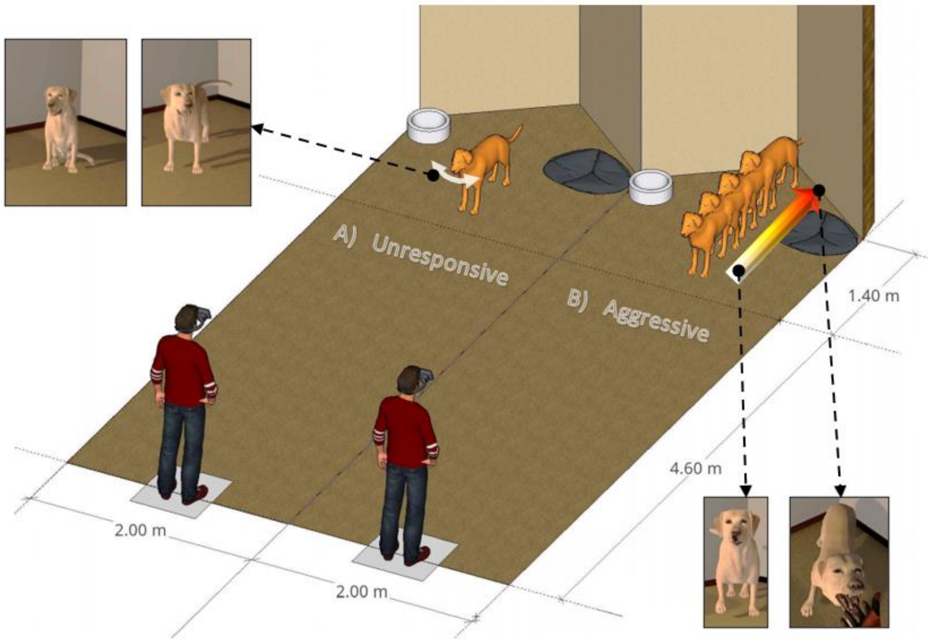


Figure 4.2 A diagram of the exploration VR task set up for a) the non-reactive scenario and b) the aggressive scenario. The participants' starting location was marked by a 30x30cm box (diagram designed using SketchUp (Trimble, Sunnyvale, CA) (human and dog model by Mike Winter)).

4.2.3.2 Tracking variables

Three-dimensional coordinate data were collected including human head position, left- and right-hand position, dog position (tip of the dog's nose) and in the aggression scenario, aggression level (0 – 9). Human head, hand and dog head coordinates (*x*, *y*, *z*) were recorded with a precision of 0.1m at a sampling frequency of 5Hz. Each coordinate position was automatically recorded in Unity software during the live experience and exported in a Microsoft Excel CSV file format.

4.2.3.3 Distance travelled and proximity to the dog

Pythagorean theorem was used to calculate the linear distance a participant travelled between two three-dimensional (*x*, *y*, *z*) points. The total linear distance travelled by a participant was calculated as the sum of all absolute linear head movements during the trial. For each participant, the closest proximity a participant's head and hands came to the dog model was calculated using the Pythagorean theorem to calculate the distance between the participant and dog model (nose) by using their three-dimensional coordinates.

4.2.3.4 Head gaze

Head gaze, defined as "*head orientation as an approximation of gaze direction*" (Atienza *et al*., 2016), refers to a ray (or pointer) originating from the centre of the HMD and points in a forward direction which identifies virtual objects the ray intersects (or collides) with, indicating the approximate direction of gaze. The object was automatically recorded in the data output at (every 0.2 seconds (5Hz)) and indicated if the gaze was directed towards the dog or not.

4.2.3.5 Time taken to get to the highest level of aggression

In the aggression scenario, the highest level of aggression (6 – 9) an individual reached was automatically recorded along with the time (s) it took to reach the level.

4.2.4 Statistical analysis

Data management and statistical analysis was conducted in Microsoft Excel and IBM SPSS (Version 27, Armonk, NY: IBM Corp). Boxplots were developed in Origin Pro (OriginLab Corporation, Northampton, MA, USA). Open ended questions were coded and categorised using NVivo 12 (QSR International Pty Ltd).

A Wilcoxon signed rank test was used to compare total distance travelled, the closest distance to the dog, time spent gazing at the dog and total and subscale presence scores, between the aggressive and non-reactive scenario for both the combined data (AN & NA) and individual groups (AN, NA). The effect size was calculated for the closest distance a participant got to the dog ($r = z / \sqrt{}$ of N) (Pallant, 2011, p. 233). A Mann Witney U test was used to compare each scenario separately (aggressive and non-reactive) between individual groups for the total distance travelled and time spent gazing at the dog.

To test for associations between the highest level of aggression reached (6 – 9) and demographic factors a Spearman Rank Test (age) and a Fisher's Exact Test (gender, dog ownership, previous VR experience).

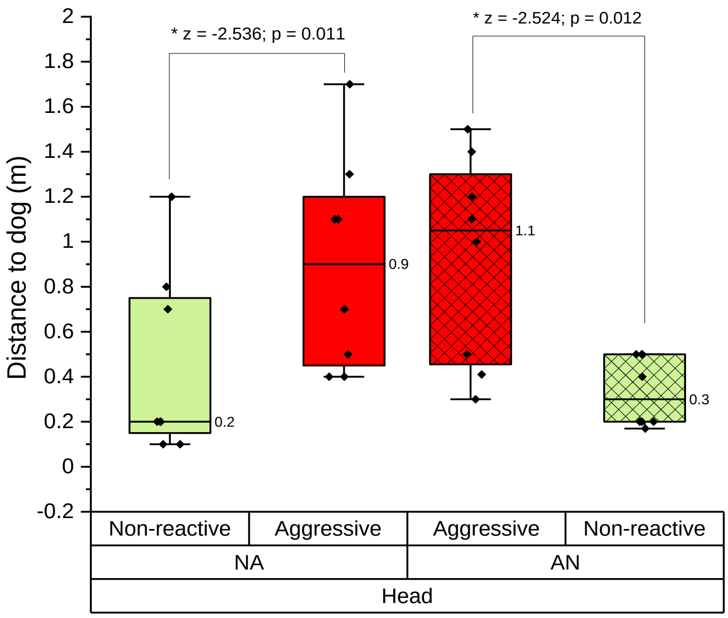
The presence questionnaire was scored based on the published scales (Witmer *et al*., 2005). The total presence score was compared for both combined data and between scenario within each group (NA, AN) using a Wilcoxon signed rank test. The SSQ was scored based on the published scale (Kennedy *et al*., 1993) and completed three times per participant. A Friedmann test was conducted to determine if there was a difference across the three times (pre-task, task 1 and task 2). A p-value of <0.05 was considered significant.

4.3 Results

4.3.1 Closest proximity to the dog

Participants' head and hand positions moved significantly closer to the dog in the non-reactive scenario than in the aggressive scenario, when all data was combined (NA & AN) (head (non-reactive Md = 0.2m, IQR = 0.2 - 0.5; aggressive Md = 1.1m, IQR = 0.4 - 1.3) (Z = -3.521; p<0.001; r = 0.6), left hand (non-reactive Md = 0.1m, IQR = 0.0 – 0.1; aggressive Md = 0.6m, IQR = 0.1 - 1.0) (Z = -3.921; p = 0.001; r = 0.7), right hand (non-reactive Md = 0.0m, IQR = 0.0 - 0.1; aggressive Md = 0.4m, IQR = 0.1 - 1.0) (Z = -3.183; p = 0.001; r = 0.6) and separately when comparing within NA and AN groups (p<0.05 in all cases (Figure 4.3a & b)).

a)



b)

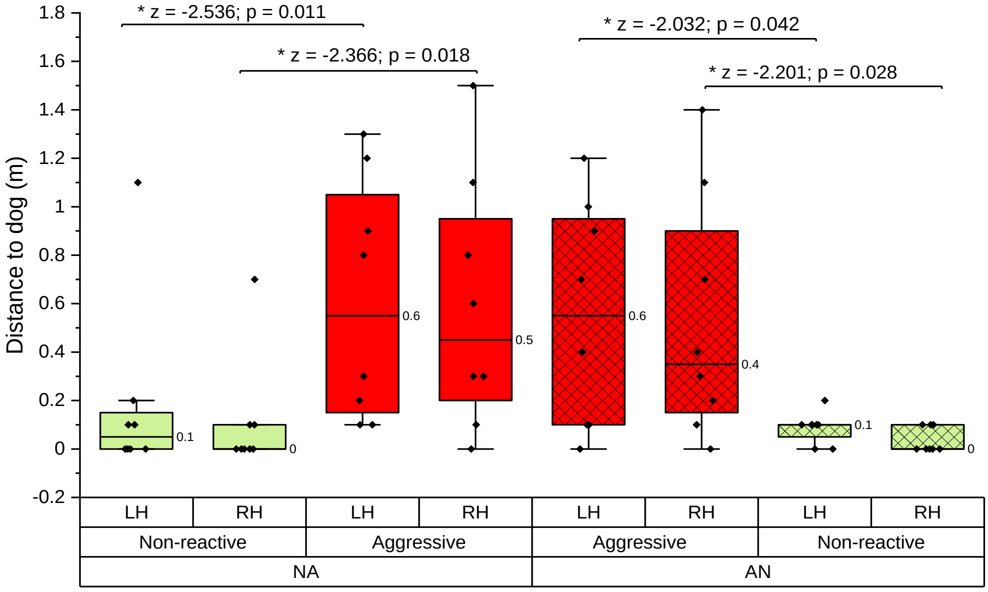


Figure 4.3a&b a) A boxplot of the closest head position in the non-reactive and aggressive scenarios where the aggressive scenario was first (AN) or the non-reactive scenario was first (NA). b) A boxplot comparison showing the closest distance the left- and right-hand got to the dog in non-reactive and aggressive scenarios, where the aggressive scenario was undertaken first (AN) or non-reactive first (NA).

4.3.2 Distance travelled - Head and hand tracking

In the combined dataset (both NA and AN) there was no difference in the median total distance travelled between non-reactive (Md = 55.9m, IQR = 36.7 – 78.0) and aggressive scenarios (Md = 56.4m; IQR = 43.8 – 76.1) (Z = -0.259, p = 0.796, r = 0.4). The total distance travelled was shorter in the aggressive scenario compared to the non-reactive scenario in group NA (p = 0.025) but not group AN (p = 0.093) indicating an order effect (Figure 4.4).

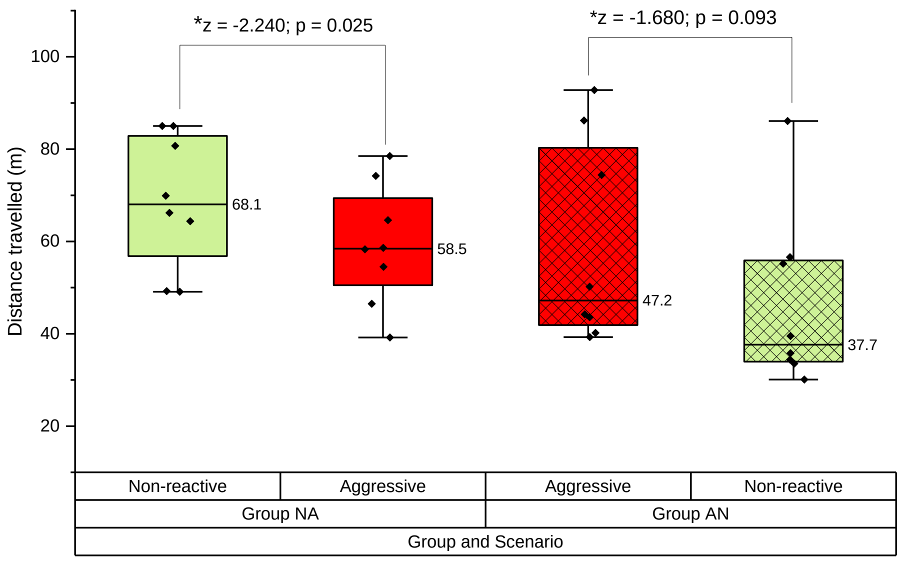


Figure 4.4 A boxplot displaying the median total distance travelled in each scenario (non-reactive and aggressive) for group NA and AN.

There was a significant difference between median total distance travelled during the non-reactive scenario in group NA (Md = 68.1m, IQR = 53.1 – 83.9) compared to group AN (Md = 37.7m, IQR = 30.1 - 56.3) (U = 12.00, p = 0.038, r = 0.5). There was no significant difference between the median total distance travelled in the aggressive scenario between group NA (Md = 58.5m, IQR = 48.5 - 73.6) and AN (Md = 47.2m, IQR = 31.1 - 83.3) (U = 28.00; p = 0.721, r = 0.1).

4.3.3 Levels of Aggression

In the aggressive scenario, one participant reached level 6, seven reached level 7, five reached level 8 and three reached level 9 (a bite). Participants who moved more slowly towards the aggressive dog also tended to stop at a lower aggression level i.e. at a greater distance from the dog ($r = -0.532$, $n = 16$, $p = 0.034$) (Appendix 4.3). Most participants (14/16) in both groups spent over 70% of their time between levels 5 – 9 (Appendix 4.4). On the first approach, six participants moved from level 1 immediately to 5, five from levels 1 to 6, four from levels 1 to 7 and one participant straight to level 8. Once participants reached level ≥5 the dog would not perform levels 0 – 2 thereafter (see Chapter 3).

The was no evidence of an association between level reached and age ($r = -0.159$, $p = 0.557$), gender (Fisher's exact $p = 0.827$), if a person currently/previously owned a dog or not (Fisher's exact $p = 0.869$), if they were previously bitten or not (Fisher's exact $p = 0.500$) or if a person had previous experience of VR or not (Fisher's exact $p = 0.191$). All three participants who reached level 9 (dog lunges and handsets vibrate indicating 'a bite') did not currently own a dog and only one had previously been bitten. All three individuals that reached level 9 agreed with the statement that they could recognise aggressive dog behaviours. However, regarding the statement about whether they could recognise a dog showing scared or fearful behaviour one respondent stated 'disagree' another stated, 'neither agree/disagree' and one stated 'strongly agree'.

4.3.4 Head gaze

Individuals that got closer to the dog spent more time gazing at the dog, in both the non-reactive (rho = -0.945; $p<0.001$) and the aggressive (rho = -0.831; $p = 0.011$) scenario in group NA only. There was no evidence of a difference in the time spent gazing in the direction of the dog model between the aggressive and non-reactive scenarios in the combined dataset (NA & AN, $Z = -1.551$, $p = 0.121$) or individual groups (NA, $Z = -0.180$, $p = 0.779$; AN, $Z = -1.680$, $p = 0.093$). The median time spent gazing in the direction of the dog model in the non-reactive scenario was lower in group NA (Md = 133.5s, IQR = 71.9 - 199.2) than AN (Md = 218.4s, IQR = 178.6 – 261.5) ($U = 11.00$; $p = 0.027$), but there was no evidence of a difference in the aggressive scenario in groups NA (Md = 144.0s, IQR = 51.8 – 207.5) and AN (Md =171.7s, IQR = 86.8 – 199.5) ($U = 29.00$, $p = 0.753$).

4.3.5 Observational feedback

There were no reported issues by participants regarding the use of the headset, handsets or the virtual experience. In most trials, there was no interference with the user due to the instructor controlling the location and position of the cable connecting the headset to the computer, and no participants reported interference. However, in a small number of experiments users did briefly appear to be aware of the wire touching them on the shoulder or if a user quickly turned around. Despite this, a range of positive anecdotal comments were made by participants both during and after the VR sessions such as "*Wow, I wasn't expecting it to look so real*". Participants attempted to interact with the dog through verbal communication (e.g., whistling, clicking, or talking to the dog model) and physical interactions (i.e., stroking the non-reactive dog). One participant started the session by walking very quickly over to the dog which lunged at them, and they subsequently screamed and jumped.

4.3.6 Behaviour recognition and interpretation

When participants were asked if they noticed anything about the behaviour of the dog, they most often referred to the movement of the dog's body as a whole or part of the body (Table 4.2).

Table 4.2 Categorised open-ended responses to the question "*Did you notice anything about the behaviour(s) of the dog*" for both non-reactive and aggressive exploration scenario. Multiple descriptions were coded separately (e.g., cowered and bared teeth were coded in two separate categories) per respondent.

Non-reactive scenario – categories	**Count**
Body	**12**
Full body/body movement	**5**
Moving from standing to sitting	3
Moving forward	1
Slow movement without hesitation	1
Head	**2**
Yawning	1
Sniffing	1
Tail (wagging)	**5**
General behaviour/emotion	**9**
Alert	1
Anxious	1
Distressed, uncomfortable	1
Friendly	1
Placid, bored	1
Relaxed, calm, happy	3
Shy	1

Aggressive scenario - Category	**Count**
Body	**17**
Full body/body movement	**10**
Moved back/backed away/retreated	7
Crouched down, cowered	2
Sitting	1
Head	**4**
Bared teeth	1
Biting, snapping	2
Ears	1
Paws	**2**
Paw raise	2
Tail (e.g. lowered, between legs)	**1**
General behaviour, emotion, description	**15**
Aggressive	3
Agitated	1
Did not like people	1
Docile at a distance /initially friendly	2
Nervous/Scared/Unsure	5

Vocalisations	**5**
Pining, yawning, whimper	2
Groaning	1
Panting	1
"No grunting sound"	1
Direction of gaze	**4**
Looking around	3
Looking at me	1
Willing to be petted	1
Distance to the participant	1

Threatened	1
Uncomfortable	1
Unfriendly	1
Vocalisations	**12**
Barked	3
Growled	8
Panting	1
Location of the dog (e.g. In the corner)	**1**

Participants frequently used adjectives to describe the emotion or motivation of behaviours of the dog rather than describing actual behavioural signals. In the non-reactive scenario, five noted the tail compared to one in the aggressive scenario. It was also evident that answers differed between the initial open-ended question asking about what a participant noticed about the behaviour of the dog and close ended questions about if they saw a behaviour. For example, in the open-ended question "*Did you notice anything about the behaviour(s) of the dog*", no participants referred to the early signs of the canine ladder of aggression model such as lip licking and only two stated the paw raise. However, when asked about specific behaviours, lip licking (56.3%; 9/16) and head turning (56.3%; 9/16) were reported albeit not commonly. The most frequently behaviours reportedly seen in the aggressive scenario were raising a paw (100%, 16/16), backing away (93.8%, 15/16), and showing teeth (93.8%, 15/16). All respondents did move through level 1 where the lip lick occurs, however, admittedly participants did not spend long there (median 6.5s and 7.7s in group NA and AN respectively). Furthermore, due to the speed of approach, all participants moved from level 1 to ≥5 and after this time level 0 - 2 was not shown again even if they moved away from the dog, as level 5 had been reached. There was no evidence of a significant difference between time spent in level 1 and if a participant stated they saw the lip lick or not ($p = 0.81$). Only one person stated they did not see the dog showing its teeth (level 7 onwards), due to this participant being the only person that did not go closer than level 6 and thus did not reach this behaviour. Interpretation of what these aggressive behaviours meant varied but generally agreed that it was some form of negative emotional state such as scared, threatened, or anxious (Appendix 4.5 and 4.6).

Regarding the three individuals that were 'bitten' (level 9), all 3 individuals stated seeing the dog showing its teeth and that it indicated a threat or warning ("aggression, defensive", "warning sign, indication to keep away", "aggressive warning sign"). Two reported noticing the earlier lip lick in the closed ended question, however, only one provided an answer as to what it meant "*not sure, maybe wanted to wet its mouth*".

All 16 participants stated they heard some form of dog vocalisation during the aggressive exploration scenario. Most reported vocalisations including growling or barking (Table 4.3).

Table 4.3 Vocalisations reported by participants in an open-ended question following the aggressive scenario (multiple responses per person).

Vocalisation	Example response	n	%
Growling	*"Growling – a warning sound the dog isn't happy"*	14	87.5
Barking	*"…Barking when I got near to intimidate me into leaving…"*	12	75.0
Snarling	*"Snarling… - aggressive, angry"*	1	6.3
Yawning	*"Yawning and noises with it. I'd interpret as signs of anxiety"*	1	6.3
"Squeaking"	*" Squeaking – uncomfortable experience and anxious"*	1	6.3
"Grunting"	*"Regular grunting with occasional breaks. The grunting seems to be his normal breathing sounds which became quicker as I approached the dog…."*	1	6.3
"Whining"	*"…Whining when I walked to show he was upset"*	1	6.3

4.3.7 Simulator Sickness Questionnaire

Findings from the SSQ were low; with seven out of sixteen participants (43.8%) scoring 0 (no symptoms) across all three surveys. Of those that did score above 0 (56.2%; 9/16), no rating went above 1, indicating a 'slight' symptom. Of which only four participants increased the total score between the pre-test and post-test indicating that there was no increase in total score between pre-test and post-tests for five participants. Mean total scores over the three surveys were all under 10 indicating 'minimal symptoms' (Appendix 4.7). The following seven symptoms scored zero over all three surveys for all participants: headache, increased salivation, "fullness of head", dizziness (closed eyes), vertigo, "stomach awareness" and burping.

4.3.8 Presence

The mean presence score, based on Witmer *et al's* (2005) presence questionnaire, was calculated (Appendix 4.8). In the combined dataset (NA & AN), total presence scores were greater for the aggressive scenario than the non-reactive scenario ($p = 0.05$) (Figure 4.5). Within-group analysis demonstrated that this was due to a difference in total presence scores when the non-reactive scenario came first ($p = 0.012$) but not when the aggressive scenario came first ($p = 0.441$) (Figure 4.5).

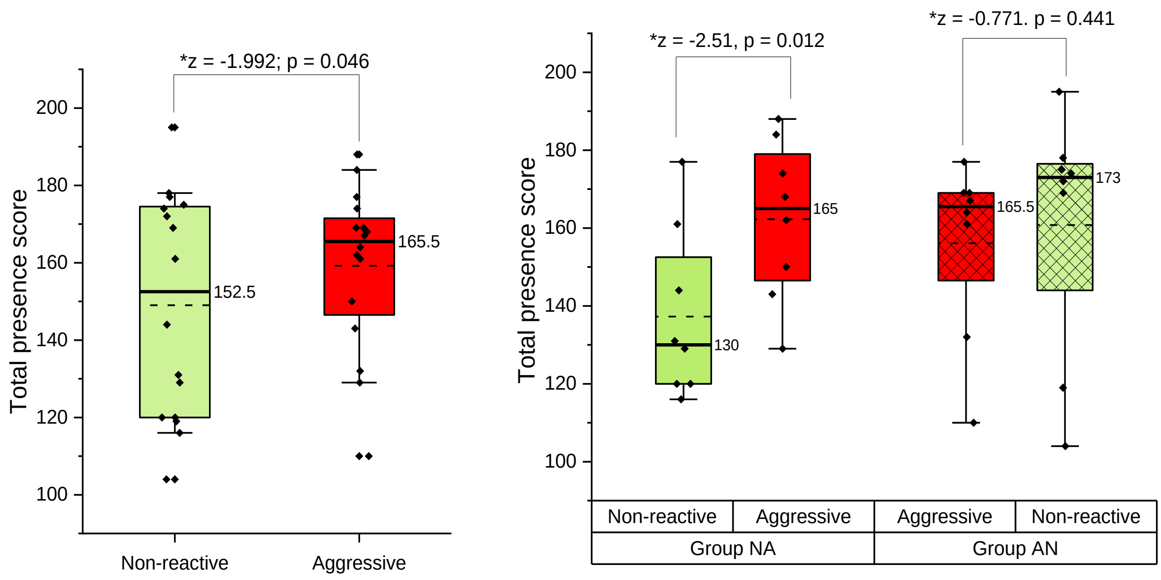


Figure 4.5 Boxplots for total presence scores and a) combined groups (NA and AN) by scenario (left) and b) comparisons between group NA and AN by scenario (right).

4.4 Discussion

The present study investigates the use of objective measures via human head and hand tracking to indicate how humans behave around a virtual dog, including one behaving aggressively towards them. This study is unique in that participants can interact with a virtual dog model via virtual reality which displays realistic behaviours based on a widely accepted theoretical model (the CLA, Shepherd, 2009) and feedback from canine behaviour experts. In addition, this study demonstrates that the virtual dog can be used to assess human behaviour (approach and avoidance) towards it. The closest distance an individual's head and hands got to the dog appeared to be the most consistent measure between conditions, whereas gaze and total distance travelled were not. Hands of participants often came within the closest distance to the non-reactive dog model and participants stayed further away from the dog acting aggressively, however three participants were still 'bitten' in this test scenario.

Participants moved closer to the non-reactive dog than the aggressive dog. Participants who moved more slowly towards the aggressive dog tended also to stop earlier and at a greater distance from the dog. This could potentially indicate that either certain individuals are more cautious or can recognise relevant earlier signals more readily and therefore approach at a slower speed. Here we found no evidence of an association between demographic factors and aggression level reached, however, the sample size was small, and although there were only four males and no statistical significance, males may have tended to reach higher aggression levels. Having said this, two out of the three participants who were 'bitten' (level 9) were female.

The total distance individuals travelled was influenced by the order in which tasks were taken. For example, in both groups, participants travelled further in the first task compared to the second task. This could be because both scenarios were held in the same environment sequential five-minute periods with a short break, and participants felt they had already explored the area fully. To account for order effects future studies could consider a randomised allocation of scenarios to each participant or consider just using the aggressive scenario given the findings in this study.

Regarding dog behaviour, vocalisations and gross body movement were the most common behaviours described by participants when asked what they noticed about the behaviour of the dog, which is similar to previous research. Kerswell *et al*. (2009) found that puppy owners most frequently used vocalisations and large body movements to describe emotional states including anger and anxiety. Tami and Gallagher (2009) found that barking was the most commonly (42.9%, 24/60) identified behaviour to describe aggressive behaviour. They also found that backing away was also a behaviour described in relation to fear. In the present study the most common behaviour describe in the gross body movement category was backing/moving away/retreated (Table 4.2). Furthermore, Lakestani *et al.* (2014) found that of the individuals (children and young adults (university students)) that correctly identified aggressive dogs through video clips, the majority (89%) did so through the identification of sounds the dog made.

It is important to note that the open-ended question responses provided different information to the close-ended questions and could highlight the perceived most important/significant or meaningful aspects of dog behaviour. When asked if they noticed specific behaviours and their meaning participants tended to describe the perceived underlying emotion or motivation (nervous, scared, threatened). Therefore, if actual specific behaviour descriptions were wanted, it would be useful to ask a separate question about the emotion(s) of the dog. In the aggressive scenario, few participants described the dog as aggressive despite three people reaching level 9 (dog lunges and bites at user). The avoidance of this term could indicate that participants attempt to justify or excuse the behaviour of the dog similar to previous research (Sanders, 1990; Sanders, 1994; Rajecki *et al*., 1998; Westgarth and Watkins, 2015); for example, one participant stated "[the dog] had a previous negative experience" or blaming themselves one participant stated, "I was too close". Dog behaviour (such as aggression) is often emphasised as the responsibility of the owner and not the dog (Westgarth *et al*., 2019; RSPCA, 2021). The attribution of the (fictional) dog having had a previous negative experience also potentially highlights the realism perceived.

The results regarding behaviour recognition are somewhat consistent with previous research. For example, just over half of the individuals in this study noticed appeasement signals such as lip licking and the head turn. The proportion of time individuals spent at aggression level 1 was low and therefore some appeasement signals could have simply not been seen. However, almost all participants agreed to the statement that they could recognise when a dog is showing aggressive or scared/fearful behaviours. Unlike Kerswell *et al*. (2009), the current study used a Labrador breed dog model and thus it is unlikely that a lack of recognition of early signals was due to paedomorphic morphological characteristics such as seen in brachycephalic breeds. Four participants stated an inaccurate interpretation of lip licking and the likely meaning in this context (e.g. too hot/thirsty). There was no evidence of an association between previous/current dog ownership status and recognition of appeasement signals including lip lick and head turning in this small sample at least. Previous research agrees that both adults (including dog owners) and children, often miss early and subtle behavioural signs of aggression such as lip licking, head turning and yawning (Kerswell *et al*., 2009; Mariti *et al*., 2012). Such a lack of knowledge of subtle behavioural signs is thought to be the reason for victims often stating that a dog bite was unprovoked (Borchelt, 1983; Overall and Love, 2001). This finding highlights the need for further educational interventions which result in appropriate behavioural change and highlights the importance of recognising early behavioural signals that may be seen but misinterpreted, as well as those behaviours that may be more obvious.

Few referred to the ears of the dog, supporting previous research involving video clips of nine breeds indicating that little attention is given to this area (Tami and Gallagher, 2009), but in contrast to Demirbas *et al*. (2016) who found that respondents highlighted the ears in 75% of cases when interpreting videos of behaviours in three dog breeds, Doberman, Boxer and Dalmatian. Differences in reliance on such bodily features could be due to the wide variation in ear morphology among different dog breeds, and in our Labrador, these will not have as dramatically changed in position as in some other breeds.

The tail movement was more commonly reported in the non-reactive dog than the aggressive scenario. This could have been due to the non-reactive dog continuously wagging its tail and the aggressive dog placing its tail between its legs for level 5 upwards, although shadows were also used in the model development to help identify the tail position. Tail wagging/movement has been reported elsewhere as the most reported behaviour in friendly/happy dog behaviours and emotions (Kerswell *et al*., 2009; Tami and Gallagher, 2009). However, tail wagging may simply indicate arousal in both positive (e.g. play) and negative (e.g. appeasement) states and the position (high, low) and type of tail wagging (stiff, relaxed, small or large movement) are likely to be more informative (Luescher, 2014).

It is important to note that the assessment of human behaviour in the present study was conducted in VR and not in a real-world scenario. Therefore, it is unclear if participants would behave in the same way with a real dog or transfer what they have learnt from VR to the real world. Future research could explore human behaviour towards a dog in both real world and virtual reality (e.g., animal assisted therapy dog) to explore similarities and differences.

Given that 32% of participants never used VR, it was positive to note that after the introduction to equipment all participants could use the equipment with no additional help from the instructor. However, there were a small number of occasions identified by the instructor where participants were aware of the HMD-Laptop cable. Such incidents could briefly affect the subjective ratings of presence or result in a break in concentration and immersion (i.e. a break in presence). Other studies have reported similar issues (Usoh *et al*., 1999; Gonçalves *et al*., 2020). The presence ratings were high, indicating that both the environment and dog model were deemed to have high levels of realism and immersion. There was evidence that the aggressive dog resulted in higher levels of presence possibly due to increased interaction which was directly related to the user's location and the dog model staring at the user.

This study provides little evidence of any cybersickness from using DAVE and thus these questionnaires are likely not needed in future research. In this study, there were only two 5-minute tasks with a 5 to 10-minute break to complete post-test questionnaires and VR simulator sickness has been associated with an increased length of exposure time (Dużmańska *et al.,* 2018; Saredakis *et al*., 2020). Secondly, the environment was relatively stable (i.e., only the dog was moving) compared to high levels of simulator sickness noted in fast moving VR environments such as roller coasters (Nesbitt *et al*., 2017). Thirdly, the setup represented naturalistic user walking movements which has been recently noted to reduce simulator sickness in VR compared to other formats (e.g., stationary game controller movement) (Lee *et al*., 2017; Saredakis *et al*., 2020). Finally, the equipment used is of a high specification and therefore reduces the likelihood of, for example, tracking or rendering delays.

A range of further research is needed such as exploration of participant demographics and prior knowledge. For example, both the gender and personality of participants require further exploration as it is widely reported that males are at a higher risk of being bitten by dogs than females (Sacks *et al*., 1996; Westgarth *et al*., 2018). Westgarth *et al*. (2018) also found that in adults, being less emotionally stable was a factor associated with an increased risk of dog bites.

As the study was described as 'to investigate human behaviour around dogs', people may have expected positive dog behaviours or human-dog interactions such as play. The perceived intention of the study could also be gathered from participants in future research. In addition, people who are familiar with VR or have an animations/virtual reality design background may be desensitised or less responsive to VR models and environments. For example, although only three people were 'bitten' the perception of those should be investigated further as to why they feel this occurred and who, if anyone, is to blame (e.g., participant, owner, dog, no one). At the start of each VR task participants were given the instruction to 'explore the area'. As this was the first-time the VR model was tested with participants in a research setting, the instructions seemed appropriate as a starting point to simply study what the users do in the virtual environment and in the presence of the dog model.

In addition, recent research has stated that exploration tasks in VR are likely to be more beneficial in comparison to previous tests, such as the Behaviour Approach Test, because; a) the exploration task doesn't require instructor involvement during the task and therefore not prone to social pressure or instructional biases and; b) the exploration task in VR allows users to move freely compared to more traditional and simplified methods that may require a limited response (e.g. press a single button to stop approaching on a computer screen (for example see Briones and Marshall., 2022) (Dibbets *et al*., 2021; Lemmens *et al*., 2024). Furthermore, the task and instructions used in the present study also removes the motivation for specific behaviors which may occur with the perceived gamification of tasks (e.g. find/collect all items) (Lemmens *et al*., 2024). However, it is possible that the instructions given by an instructor could still have influenced human behaviour in the environment and towards the dog. Simply by instructing and allowing a person to explore the area could have indicated that the dog is not a threat or a danger and therefore participants may have moved closer than in the same situation in real-life. Previous research has used similar instructions with children and parents in the presence of an unknown dog. For example, Morrongiello *et al*. (2013) explored child behaviour in the presence of a live dog before and after an educational intervention. The assessment session occurred in a laboratory setting with a live dog and the children were instructed to "Do whatever they wanted". The authors suggest that parents may have allowed that children to get close to the dog due to their assumption that the dog was safe to approach. Therefore, future research needs to carefully consider the impact of instructions on human behaviour and the setting (e.g. laboratory, naturalistic) in which the task is performed. Future consideration is also needed regarding the potential implications of the VR practical sessions may have on human behaviour change in a real-life scenario especially regarding the approach a dog displaying aggressive behaviour. This also highlights the importance of incorporating detailed dog bite prevention information into practical VR sessions.

During the exploration task, the participants often stated "*I don't know what to do*" after approximately 2–3 minutes of interaction with the dog and exploring the area. Therefore, we suggest reducing the experiment time from five to two minutes. A larger area than the current 6x2m might be useful to encourage people to explore the area, however, space availability is often a limitation with room-scale 'real walking' VR (when compared to controller-based, teleportation or motion-based locomotion techniques which allows larger virtual areas) (Boletsis, 2017).

Given that vocalisations were one of the most recognised behaviours, further research comparing user interpretation and recognition of behaviours in scenarios with and without vocalisations would be useful. Furthermore, as previously stated a range of physical characteristic could play a role on human response which could be explored such as the effect of skull shape, size, coat colour or tail movement (e.g. position, wagging frequency and different lengths). There were frequent attempts at physical interaction with the non-reactive dog, which appeared to indicate an individual attempting to stroke the virtual dog. Further development of the model could include haptics (for example tactile props (a model dog) or haptic feedback, such as controller vibration). Verbal communication directed towards the dog model was also noted in the current study, as reported in previous VR and AR related research involving both AR and VR dog models. For example, Norouzi *et al*. (2019) found that participants called the dog's name or used terms to get the attention of the dog. Future studies should record verbal comments and physical and emotional reactions during the task (e.g. in one case a person jumped and screamed when quickly approaching the aggressive dog which lunged), including at what time and during what scenario they occurred.

This study was not without limitations. The sample consisted of only university students, however, this included both undergraduate and postgraduate from a range of backgrounds and areas of study. Furthermore, the sample size was also low and therefore results need to be interpreted with caution. Most participants were female, a gender bias often seen in studies relating to human-animal interactions (Herzog, 2021). Interestingly, in contrast, VR studies often report a bias in male participants (Peck *et al*., 2020). Furthermore, participants were not asked if they had previously taken part in dog safety training which may have resulted in differing behaviour and approach distances towards both aggressive and non-reactive dogs.

It is important to note that only a single coordinate on the dog model was placed on the dog's nose. Therefore, more points are needed to ascertain how close individual hands get to other areas of the dog (e.g. the back of the head). The dog model was limited to the reaction to a person based on their speed of approach and distance of the participant. In a real-world scenario, a dog may perceive threats by a participant that were not included such as eye contact, facial expression, posture and specific behaviours (Somppi *et al*., 2016), which could be development ideas for the future as technology advances. Having said this, the research presented in this study would be unlikely to have been conducted in a real world setting due to the welfare concerns for both human and dogs.

The recognition of yawning was not included due to trying to minimise the length of the questionnaire. However, it was mentioned by several participants either by observing the behaviour or hearing the vocalisation. Some behaviours which may be evident in a real dog were not present due to development limitations, such as piloerection which has previously been reported in aggressive behaviours, but often are not identified by participants (Tami and Gallagher, 2009).

4.5 Conclusion

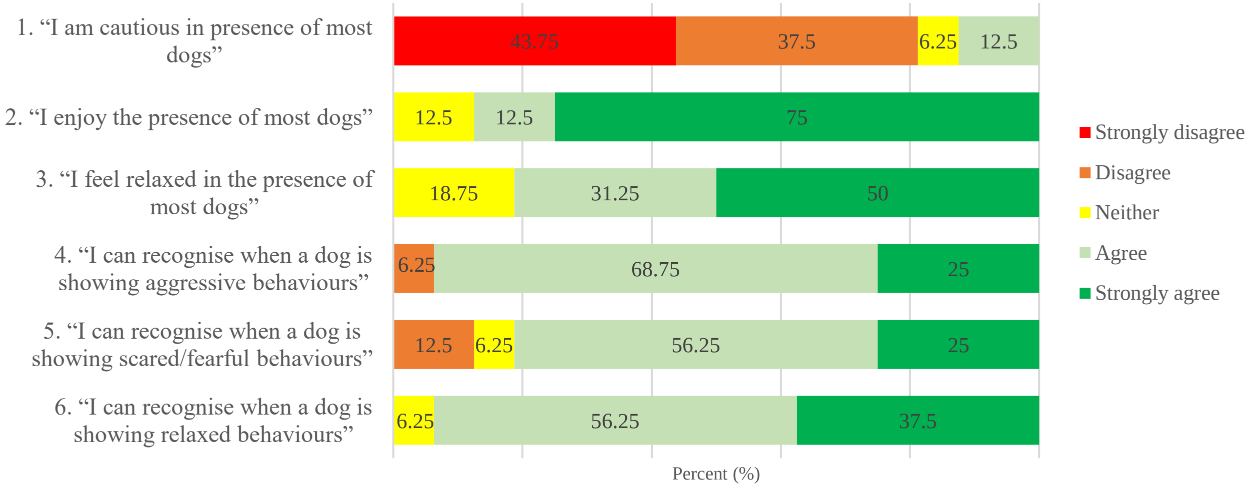
This study tested a range of objective and subjective measures which were modulated by the dog model's non-reactive and aggressive conditions. Participants moved significantly closer to the non-reactive dog model compared to the aggressive dog model, indicating they perceived it as less of a threat to them, as supported by their reported interpretations. Participants most often focused on body movements when describing behaviours often stated emotional or motivational justifications for behaviours seen, and also noticed vocalisations. Participants appeared to perceive the dog model as realistic and simulator sickness was not an issue.

APPENDICES TO CHAPTER 4

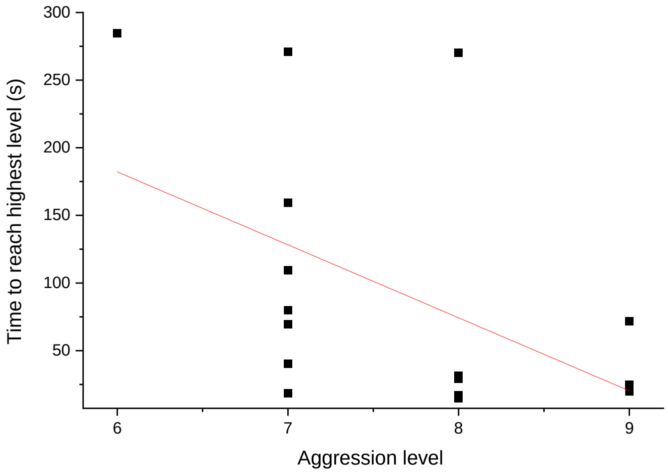
Appendix 4.1 Survey questions about dog behaviour recognition and interpretation.

<table>
<tr><th colspan="2">Questions</th><th>Answers</th></tr>
<tr><td colspan="2">Did you notice anything about the behaviour of the dog?</td><td>Open ended</td></tr>
<tr><td colspan="2">What do you think the behaviour indicated about the dog?</td><td>Open ended</td></tr>
<tr><td colspan="2">Did you see the dog [Behaviour]?</td><td rowspan="2">Yes, No
[For each behaviour with an image of the behaviour being displayed in the relevant scenario]</td></tr>
<tr><td>Aggressive:
‘lip lick’, ‘raise its paw’, ‘lying down’, ‘turn its head away’, ‘backing away’, ‘showing its teeth’, ‘standing’</td><td>Non-reactive:
‘lying down’
‘standing’</td></tr>
<tr><td colspan="2">What do you think this behaviour meant?</td><td>Open ended [for each behaviour]</td></tr>
<tr><td colspan="2">Did you notice any dog related sounds/vocalisations?</td><td>Yes/No [Aggression only]</td></tr>
<tr><td colspan="2">If Yes, please describe what you heard and what you thought these sounds/vocalisations meant?</td><td>Open ended [Aggression only]</td></tr>
</table>

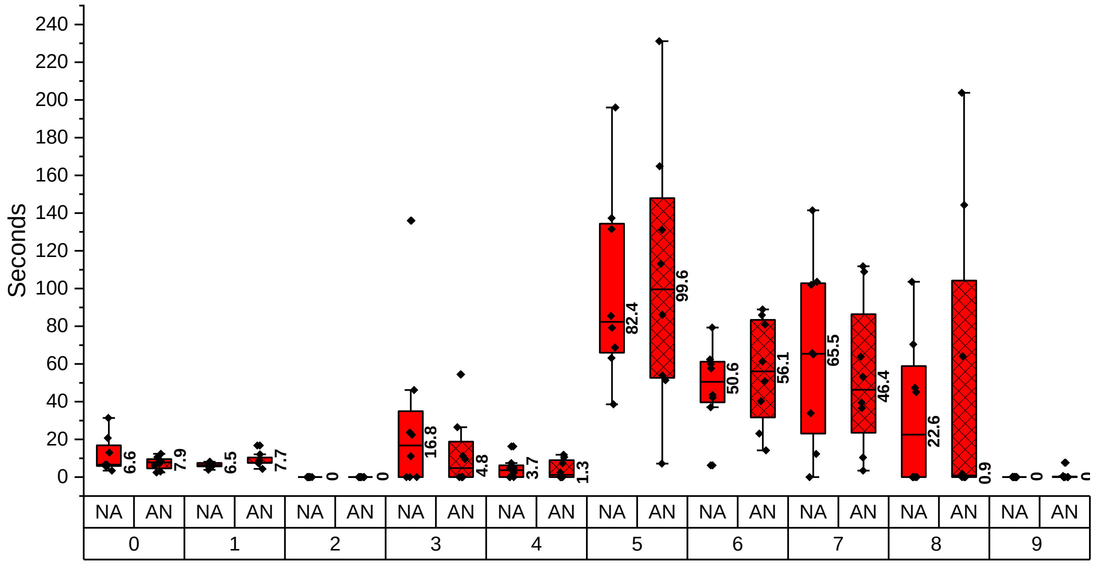
Appendix 4.2 Participants responses to six statements relating to their feelings in the presence of dogs and perceived ability to recognise dog behaviours (n =16).



Appendix 4.3 The highest-level participants reached, and the time taken to reach the highest level.



Appendix 4.4 A boxplot comparison displaying the median time participants in each group (NA/AN) spent in each level of aggression (0-9) over the five-minute aggression task.



Appendix 4.5 Categorised open-ended questions when asked to describe overall behaviour ("*Describe what you think the behaviour(s) indicated about the dog*") (multiple descriptors allowed per respondent).

Non-reactive Scenario	**n**
Relaxed, comfortable, calm, happy, nice	8
Wanted attention, loving, waiting for someone	4
Anxious, nervous	2
Yawned and whined	1
Unhappy	1
Wagging tail and breathing	1
Uncomfortable	1

Aggressive Scenario	**n**
Nervous, anxious, stressed, scared/unsure around people, timid, afraid	13
Threatened	3
Negative previous experience/treatment	3
Defensive/ready to defend	3
Unfriendly/ Not in a good mood	2
Confused	1
Aggressive	1
Not confident	1
Lost	1

Appendix 4.6 Perceived meaning of specific behaviours (lip lick, paw raise, head turn, backing away and showing teeth) regardless of whether a participant saw the behaviour during the scenario or not (n = 16). (Multiple responses were allowed per person).

Behaviours	**n**
Lip Lick	
Hungry or thirsty / Too hot	4
Nervous / Unsure / Anxious	3
Warning to back off / Ready to defend itself	2
Aggressive	1
Comfortable	1
Did not answer the question	5
Paw Raise	
Anxious / Worried / Scared / Wary / Unsure	6
Actual or preparation for movement towards/away from the user (e.g. Preparing to move / lunge / run away / 'come at you')	5
Submission	2
Attention (e.g. "He wanted something")	1
Beginning to feel at ease	1
Enticing (e.g. "At first it looked like it was inviting...")	1
Hurt paw	1
Defensive	1
Saying hello with their paw	1
Waiting on user response to see if they would get closer	1
Head Turn	
Looking around the environment for threats/distracted/disengaged	5
Lack of eye contact (e.g. Does not like eye contact / No eye contact)	3
Did not want to interact	2
Threatened (e.g. Perceived user as a threat)	2
Feeling safe	1
Following a moving object (e.g. user moving arms)	1
Submission	1
Nervous / Unsure	1
Did not answer the question	4
Backing away	
Nervous / Anxious / Scared / Frightened / Wary / Unsure / Distressed	8
Dog perceived user as a threat / distance increasing behaviour (e.g. dog moved back as user moved forward / Removed itself from the situation)	9
Defensive	2
Snarled	1
Did not answer the question	1
Showing its teeth	
Trying to get user to move away (e.g. Warning to back away / I was too close / Trying to make me leave)	8
Aggressive	5
Frustrated / Angry / Scared / Upset / Not happy	4
Trying to intimidate / scare me	2
Warning behaviour / sign	2
Defensive / defend itself	2
Territorial	1

Appendix 4.7 A Friedmann test found that there was no significant difference between total mean weighted scores (n = 16) by either scenario (pre-test-non-reactive-aggressive) (p = 0.387) or by order of tasks (pre-test-1st task-2nd task) (p = 0.911). Furthermore, there was no significant difference in total scores within group NA (pre-test-aggressive-non-reactive) (p = 0.905) or within group AN (p = 0.61). Weighted SSQ scores including nausea, oculomotor, disorientation subscales and total scores.

	Pre-Test SSQ score			Non-reactive SSQ score			Aggressive SSQ Score		
Subscale	**Mean**	**S.E.**	**S.D.**	**Mean**	**S.E.**	**S.D.**	**Mean**	**S.E.**	**S.D.**
Nausea	2.98	1.14	4.57	3.58	1.48	5.91	5.37	2.30	9.20
Oculomotor	5.69	1.62	6.49	5.69	1.90	7.58	8.53	3.01	12.02
Disorientation	0.87	0.87	3.48	4.35	2.10	8.38	3.48	2.01	8.04
Total*	4.21	1.18	4.71	5.38	1.74	6.96	7.25	2.59	10.35
Task order	**Pre-Test**			**1st Task**			**2nd Task**		
Nausea	2.98	1.14	4.87	3.58	1.48	5.91	5.37	2.30	9.20
Oculomotor	5.69	1.62	6.49	7.11	2.01	8.05	7.58	2.68	10.27
Disorientation	0.87	0.87	3.48	3.48	2.01	8.04	4.35	2.10	8.38
Total*	4.21	1.18	4.71	5.84	1.74	6.96	7.01	2.18	8.73

**Total score is calculated by the addition of nausea, oculomotor and disorientation raw (unweighted) scores and multiplied by 3.74 (Kennedy et al., 1993).*

Appendix 4.8 Subjective mean scores and standard deviation from the 29-item presence questionnaire split by the four-factor model (Witmer *et al*., 2005) with internal consistency (Cronbach's alpha (C *α*)).

	Aggressive (n=16)					Non-reactive (n=16)				
Factor	**Item**	**Mean**	**SD**	**Factor mean. (SD)**	**C *α***	**Item**	**Mean**	**SD**	**Factor mean. (SD)**	**C *α***
Involvement	1	4.69	1.537	5.20 (0.977)	0.857	1	3.56	2.220	4.76 (1.045)	0.931
	2	5.56	0.892			2	3.88	2.125		
	3	4.75	1.528			3	4.44	2.159		
	4	5.44	0.964			4	4.81	1.682		
	6	5.88	1.408			6	5.75	1.653		
	7	5.63	1.147			7	5.38	1.258		
	8	5.44	1.413			8	5.00	1.366		
	10	6.25	0.775			10	6.06	0.998		
	14	6.06	1.124			14	6.00	1.095		
	17	2.94	1.611			17	2.63	1.628		
	18	5.88	1.025			18	5.31	1.537		
	26	3.88	1.996			26	4.31	2.358		
Sensory Fidelity	5	5.50	0.894	5.02 (1.252)	0.784	5	4.69	1.740	4.96 (0.852)	0.772
	11	6.44	0.727			11	5.94	1.063		
	12	5.94	0.854			12	5.44	1.153		
	13	2.94	1.879			13	3.44	2.032		
	15	4.38	1.408			15	5.13	1.408		
	16	4.94	1.340			16	5.13	1.408		
Adaption/ Immersion	9	5.31	1.621	5.99 (0.378)	0.822	9	3.63	1.996	5.57 (0.859)	0.859
	20	6.63	0.619			20	6.63	0.806		
	21	5.69	1.448			21	5.75	1.342		
	24	5.94	1.181			24	5.56	1.153		
	25	6.06	0.772			25	5.56	1.031		
	27	6.06	1.063			27	5.63	1.360		
	28	6.13	1.408			28	6.00	1.265		
	29	6.06	0.854			29	5.81	0.981		
Inter-face Qualit	19	6.13	0.885	6.27 (0.129)	0.603	19	6.13	1.088	6.15 (0.035)	0.387
	22	6.38	1.025			22	6.13	0.957		
	23	6.31	0.946			23	6.19	0.981		

CHAPTER 5. AN ASSESSMENT OF APPROACH-STOP TASK IN THE PRESENCE OF AN AGGRESSIVE DOG MODEL AND THE EFFECT OF COAT COLOUR

5.1 Introduction

Hall (1966) proposed the Classical Proximity Theory and introduced the term 'Proxemics', which refers to the use of space by an individual such as the interpersonal (human-human) distance between two individuals that are interacting (also known as interpersonal space). Hall (1966) identifies four different spatial zones and distances for humans which include intimate, personal (or peri-personal space), social and public. Research indicates that multiple factors such as age and gender are likely to influence interpersonal distances between humans (Sorokowska *et al*., 2017). Interpersonal distance is also likely to be highly dependent upon an individual's perception of a conspecific (i.e. are they dangerous). This is especially the case during the interaction between humans and non-human animals. Recently Briones and Marshall (2022) conducted a 2D virtual approach-stop task, via a PC, which explored interpersonal distance between a virtual human avatar and varying virtual dog breeds with a handler which were perceived to be either high (e.g. Doberman, Rottweiler) or low (Golden retriever, Bassett hound) in aggression. They found that the perception of dog breed aggressiveness and a participant's affinity with dogs determined the proximity individuals got to the virtual dog. However, in the latter study was based purely on visual appearance of breeds and the dog did not display any behaviours. To date there appears to be limited research focusing specifically on the effect coat colour has on interpersonal distance between humans and dogs. As stated in Chapter 2, Suied *et al*. (2013) conducted a study using a virtual dog model with participants who were fearful of dogs and found that individuals were found to be more frightened of a virtual dog with a dark coloured coat compared to models with a brown or white coloured coat.

The impact of dog coat colour on human perceptions of dogs and their subsequent treatment of dogs has been researched in a range of contexts, specifically linked to possible biases towards dogs with black coats. The phrase 'Black Dog Syndrome' or 'Big Black Dog Syndrome' is often used to describe a bias in the context of dog adoption, rehoming and relinquishment (Woodward *et al*., 2012). A range of research has been conducted on dog rehoming and the potential role coat colour has on various factors e.g. relinquishment, length of stay, willingness to adopt, adoption rate, and euthanasia rates (Brown *et al*., 2013). Previous research presents evidence for (Posage *et al*., 1998; Lepper *et al*., 2002) and against this phenomenon (Diesel *et al*., 2008; Brown *et al*., 2013; Svoboda and Hoffman, 2015; Nakamura *et al*., 2020; Trevathan-Minnis *et al*., 2021). However, this area is likely to be complex due to varying potential confounding factors including dog (e.g. age, size, breed, genetics, behaviour, training), shelter (e.g. geographic location, lighting, management) and the individual human (e.g. perceptions, preference, dog owner experience). For example, Kobelt *et al*. (2007) video-recorded problem behaviours in Labradors kept in back gardens in Australia and found that yellow Labradors with no formal training were more likely to display problem behaviours (e.g. barking, chewing objects, digging) compared to Labradors that were not yellow (i.e. chocolate or black). The authors suggest coat colour may be genetically predisposed to specific behaviours or responses. More recently Engdahl *et al*. (2023) reviewed veterinary records and found that solid colour, in particular golden coloured and male, English Cocker Spaniels were more likely to display aggression compared to those with two coat colours (bicoloured) and were female. In contrast Lofgren *et al*. (2014) surveyed UK Labrador retriever owners and found that chocolate-coloured Labradors were reported by owners to be more excitable and less trainable than black and yellow Labradors respectively. Further, van Rooy and Wade (2019) found that, through a survey of Australian Labrador owners and genetic testing, there was no evidence of increased aggressiveness and hyperactivity in chocolate-coloured compared to yellow or black Labradors. These studies highlight the role of human perception on perceived dog physical appearance and behaviour which in turn could affect human behaviour in the presence of dogs.

Perceptions of dogs have been explored through the use of images and videos. Woodward *et al*. (2012) conducted two studies exploring the perception of breed, size and coat colour. One study used four images of standard (black and white) and toy (black and white) Poodles. They found that the small white dog was more negatively perceived than the large white and black dogs. The second study took into account eight popular dog breeds, including the Labrador, and found that breed also influences individual perceptions of dog personality i.e. stereotypical breeds (e.g. in comparison to the image, the Labrador (black), the German shepherd (black and tan), Pit Bull (brown), Rottweiler (black and tan) scored higher in dominance, hostility and lower in friendliness) irrespective of coat colour. Having said this, the black Labrador was perceived to be more hostile and less friendly and dominant than a similar breed i.e., a light-coloured Golden Retriever. Fratkin and Baker (2013) used photographs of two dogs to explore individuals' perceptions of a dog's personality based on their coat colour (black or yellow) and ear shape. Dogs with a yellow coat were seen as significantly more agreeable, conscientious, and emotionally stable compared to black dogs. However, only two dogs were used, a single dog was used for the assessment of coat colour where the colour was digitally changed (black and yellow) and another dog for ear shape (pointed or floppy) where ear shape was digitally altered. Furthermore, the image of both dogs was lying down on grass and the breeds of dog used were not mentioned. Limitations of these studies are difficulties in comparing like-for-like except the factor under consideration and are restricted to the use of still images only.

As previously discussed, human behaviour in the presence of dogs may be influenced by multiple dog related factors such as coat colour or size. But human psychological factors, such as personality traits (i.e., extraversion, agreeableness, conscientiousness, stability), interaction style or owner-dog attachment, have also been reported to be influential on factors such the as type of dog breeds (e.g. perceived to be aggressive or non aggressive) that are owned (Wells and Hepper, 2012), the impact on dog behavior, specifically the prevalence of behaviour problems including aggression (O'Farrell 1995; Podberscek and Serpell, 1997; Cimarelli *et al*., 2016; Dodman *et al*., 2018; Gobbo and Zupan., 2020) and dyadic (human-dog) performance in tasks/training (Kotrschal *et al*., 2009; Kis *et al*., 2012; Bender *et al*., 2023), but not in all cases (Stevens *et al*., 2021). For example, Podberscek and Serpell (1997) assessed the personality traits of 285 Cocker Spaniel owners via a questionnaire and asked owners to rate their dogs level of aggression. They found that owners of dogs rated as high in aggression were more tense, less emotionally stable and shy in comparison to owners who rated their dog as low in aggression. However, less research has compared personality traits between dog owners and non dog owners in the presence of unfamiliar dogs. Although Johnson and Rule (1991) found no difference in personality traits (including self-esteem, extroversion, and neuroticism) between 82 pet owners and 48 non-pet owners. Furthermore, human personality traits and how these relate to safe or unsafe behaviours, interaction style and injury risk relating to dogs and aggressive behaviour has been infrequently explored. Westgarth *et al*. (2018) found that in a community survey of households', individuals reported to be higher in the personality trait 'emotional stability' were at a lower risk of reporting to have been previously bitten by a dog. Despite this, to the authors knowledge no research has been conducted focusing on both owners' and non owners' personality traits and the potential effect these have on behaviour in the presence of an unfamiliar virtual dog displaying signals indicating defensive aggression in a confined space.

There has been minimal research focusing on dog and human related factors affecting the proximity between humans and dog especially in cases where a dog is displaying behaviour indicating it is trying to avoid a situation or displaying threatening behaviour. Therefore, the aims of this study were to:

i) Identify if there is a difference between participant closest distance to the dog model, based on the final placement of handsets, between the two dog coat colour conditions.
ii) Identify if a change of speed occurs pre and post aggression level changes.
iii) Identify if there is a relationship between participant demographic variables and personality traits and the closest distance a participant gets to the dog model, based on coat colour.
iv) Explore if heart rate differs between baseline and VR tasks either by order or coat colour.

5.2 Method

5.2.1 Participants

5.2.1.1 Recruitment

Recruitment of study participants occurred through an advertisement with a link to a recruitment survey distributed through the University of Liverpool (e.g., online departmental newsletters; university wide news emails) between the 04/02/2022 and 14/03/2022. Participants who were eligible to take part in the practical were identified through the online recruitment survey and included those who were a student at the University of Liverpool (but were not veterinary or bio veterinary students), not scared of most dogs or had a phobia of dogs, did not have epilepsy and had normal vision (including corrected with glasses or contact lenses).

Those who were ineligible based on the latter questions were automatically excluded based on their answers in the survey. Participants were asked a range of demographics questions (age, sex, ethnicity, education level) and experience with dogs (previous or current dog ownership, length of ownership, previously bitten (causing bruising or a puncture to the skin), average frequency of contact with dog and if they current or previously have had a dog related job). Six Likert dog related question were asked, three about participants about their feeling (cautious, enjoy, relaxed) in the presence of most dogs and their perceived ability to interpret dog showing scared/fearful, aggressive or relaxed behaviours. Finally, participants were asked if they had previous experience in using VR and if they would like to take part in the practical VR task, if they wanted to take part in the optional heart rate tracking part of the study and finally asked for their name, email address and phone number.

5.2.1.2 Sample size and demographics

For each participant who took part in the practical study there were three parts, the pre-task session, task 1 and task 2. Based on previous studies (see Chapter 4), and a priori analysis (Effect size = 0.5 alpha = 0.05; power = 0.80) indicated, that a sample size of 32 was required to detect significant effects. Practical sessions took part between the 1st and 24th March 2022.

A total of 18 participants took part in the two practical tasks, all of which were students at the University of Liverpool and met all inclusion criteria. Participants were aged from 18 to 35 (mean = 21.8; SD = 3.81), 61.1% were female, white and educated to A/AS level (Appendix 5.1). Over half (55.6%) reported to have a previous experience with VR. Regarding dog ownership, 77.8% currently or previously owned a dog and of these 64.3% (9/14) had owned dogs for seven years or longer. Five (27.8%) participants had previously been bitten by a dog causing at least a bruising or a puncture to the skin (Appendix 5.1) Most participants agreed that they enjoyed (94.4%) and felt relaxed (91.5%) in the presence of most dogs and 94.4% disagreed that they were cautious in the presence of most dogs. The majority agreed that they could recognise when a dog is showing aggressive (94.5%), scared/fearful (83.4%) and relaxed (77.8%) behaviours (Appendix 5.2).

5.2.2 Ethics

This study was approved by the University of Liverpool's Institute of Life and Medical Sciences Research Ethics Committee (Ref. 5259 (amendment)) and conducted in compliance with the Declaration of Helsinki.

5.2.3 Materials

5.2.3.1 Dog model appearance, behaviour and scenario

Two virtual models were used in this study which were the same apart from the coat colour which included one model with a yellow coat and one with a black coat (see example in figure 5.1). The dog models behaviour, based on the CLA, distances and levels of aggression, appearance (apart from the black coat colour), environment were the same as described in Chapter 3 and 4.

Figure 5.1 DAVE dog model with yellow and black coats displaying the raise paw and head turn.

5.2.3.2 Virtual reality equipment

As stated in Chapter 3, the VR headset was a HTC Vive Pro (HTC, Taiwan) with the accompanying Vive Pro handsets. The VR headset was tethered to a MSI Titan laptop which ran the DAVE application. All equipment used were cleaned after each participant and hand sanitiser was available for participants to use.

5.2.3.3 Heart rate tracker

Heart rate was recorded using the Polar H10 heart rate chest strap and sensor (Polar Electro Oy, Finland) placed directly on the skin over the breastbone (also see 5.2.5.4).

5.2.4 Task procedure

5.2.4.1 Pre-task session

Prior to the first task participants were asked to read an information sheet discussing the study and complete and sign and initial a consent form. Upon completion participants were asked if they had any questions before proceeding. In the recruitment survey participants were asked if they would be interested in taking part in the Heart Rate tracking part of the study. Participants were asked this again, and if so, participants were shown by the instructor how to fit the chest strap and Heart Rate monitor as per the equipment (Polar H10) instructions (Polar, n.d.). After each participant the chest strap was cleaned. Once fitted, participants were asked to complete a survey using the Ten Item Personality Inventory (TIPI) (Gosling *et al.*, 2003). Once the survey was complete participants heart rate monitor recorded for a one-minute period to be used for a baseline for comparisons with the two practical VR tasks.

5.2.4.2 Virtual reality tasks

All participants were asked to take part in two VR tasks. Prior to the practical sessions all participants were randomly allocated, using Excel's 'RAND' function', to either a yellow or black, medium sized dog in an indoor environment as the first task followed by the other colour in the second task. Prior to the start of the task all participants were introduced to the equipment (e.g., handsets and the HMD), by the instructor, explained the virtual safety grid and provided instructions on the task. This included instructions on what to do if they wanted to stop at any point by either taking the headset off or saying 'stop'. Participants were asked to stand in a 30cm-by-30cm box outlined on the floor by masking tape. The starting position was five metres from the middle (centre) of the virtual dog model. The headset was fitted to each participant and the handsets provided. Participants were instructed to stand still until the virtual environment appeared where they could then move within the confines of the virtual safety grid. Participants were instructed that once the environment appears you can start to move and to place both handsets down on the floor and let go if or when you felt at the closest distance you feel comfortable to the dog. Once the handsets were placed on the floor and each participant had let go, the VR simulation was stopped. Participants were then asked to complete a post task questionnaire.

5.2.4.3 Post task survey

Each participant was asked to complete the same survey after each of the two practical tasks (see surveys here: https://tinyurl.com/JOxleyPhDDigital). The post task survey started by asking about if the person saw the dog, if they stopped approaching the dog and an open-ended question about the reason why they stopped. Questions about the dog behaviour were asked including a closed ended question asking "*why did you think the dog was behaving in this way*". Closed ended answers were developed based on previous results (Chapter 4) (e.g. the dog's owners are not present, the dog is scared/fearful of me approaching it, the dog is relaxed, happy to see me, in pain or unwell, wants to play, has had a bad past experience, is not well trained/socialised, trying to protect it's bowl/bed/area, I don't know or other). Participants were then asked about individual behaviour that the dog displayed including lip licking, paw raise, head turn, backing away, showing its teeth and yawning. Two close ended questions followed each behaviour including: what you think this behaviour is communicating (e.g. It is… not a threat, dominant, tired, a threat, in pain, thirsty too warm, other, I don't know); what the main emotion the behaviour represents (anger, anxiety, calm/relaxed, excited, frustrated, happy/friendly, sad/upset, scared/fearful, shy, other, I don't know). Participants were also asked about dog related sound or vocalisations they heard. If answered yes participants were asked what they heard (e.g. Breathing/panting, barking, growling, sounds when the dog lick its lips, yawning/whining, and other). A multiple-choice question asked who was to blame for the dog behaving in the way it was with options including 'the dog', 'the owner/caregiver', 'yourself (the person approaching the dog', 'no-one' and 'I don't know'.

The final section of the questionnaire included three questions about the perceived realism of the dog model (appearance, behaviour, vocalisation) compared to a real dog. A further two questions were asked, one about the realism of the environment and another about the realism of users' movement in the virtual environment compared to the real world. Finally, the participants were asked to complete the Igroup Presence Questionnaire (Schubert *et al*., 2001) consisting of 14 Likert scale (0-6) questions.

5.2.5 Tracking variables

5.2.5.1 Total distance travelled

As described in Chapter 4, total distance a participant travelled was calculated using Pythagoras theorem and from three dimensional points (x, y, z) based on head position and the sum of these points, assuming linearity.

5.2.5.2 Closest distance to the dog and placement of handsets

Distance from the dog was measured by closest distance the individual head got to the dog based on their placement of the handsets. It important to note that participant could get closer to the dog and then move backwards before placing the handsets down.

5.2.5.3 Speed of approach pre and post level changes

To identify the change in speed (distance(m)/time(s)) between behaviour levels, including levels 5 (i.e. paw raise and head turn), 6 , 7 and 8, the mean distance from the starting point (5 metres from the central point of the dog) and the standard deviation per data collection point (i.e. 0.2s), was plotted over the five seconds pre and five second post each level change and a piecewise linear function (PWL2; two linear segments) was fit to the data. Each distance for both pre and post level change was divided by the time (five seconds) to determine the speed of approach.

5.2.5.4 Heart rate

The Polar H10 heart rate sensor was wirelessly paired via Bluetooth to a mobile phone with the Polar Flow application (Polar Electro Oy, Finland) and has a sampling frequency of 1Hz and has been previously validated in previous research (Merrigan *et al*., 2022) and also used as a criterion (Müller *et al*., 2019). Participants heart rate was monitored on three occasions including the pre task session and during task 1 and 2. Heart rate (bpm) was recorded from the start of the task until the point that the task was finished (i.e. the tasks was stopped by the instructor after the participant placed the handsets on the floor). Heart rate data (bpm) was automatically generated through the Polar flow app. The start of the heart rate data timings was matched with the start and end of the virtual reality task. The difference between tasks was tested both in terms of the condition (black or yellow) and the order of the tasks (first or second task, regardless of condition).

5.2.6 Data analysis

Descriptive analysis was used to describe the participants demographic and dog experience data, along with average personality scores across the sample, behaviour recognised in the model dog, blame for the behaviours observed and the realism and presence within the VR environment.

To rule out the impact of longer durations within a specific condition, time spent in each condition (i.e. coat colour) and order effects were tested using Wilcoxon signed rank test. Additionally, the total distanced travelled for all conditions combined (i.e. both yellow and black dog tasks), and each condition (i.e. coat colour and for order effects, first and second task), was analysed using Wilcoxon signed rank test.

To identify if there were any order effects or difference between the coat colour conditions and closest distance (handset placement) to the dog model, a Wilcoxon signed rank test was used. All participants' speed was then compared prior to and after each level change, using a Wilcoxon signed rank test.

To test for differences between participant demographic variables and the closest distance a participant got to the dog model, Mann-Whitney U tests were conducted per condition (i.e. yellow and black dog model). To explore links between personality traits and the closest distance a participant got to the dog model, Spearman rank correlations were used. Finally, to explore if heart rate differs between baseline measurement and each VR task, either by order or coat colour, Wilcoxon-signed ranked test and size effect calculated due to the smaller sample size.

5.3 Results

5.3.1 Personality

Regarding the five personality traits, the median score for extroversion was 4.8 (range: 2.5-6.5), agreeableness 4.8 (range: 3.0 - 6.0), conscientiousness 5.0 (range: 1.0 - 6.0) emotional stability 5.0 (range: 1.5-7.0) and openness 5.5 (range: 3.0 - 7.0). There was no evidence of a difference in personality trait scores for all five traits ($p>0.05$) between males and females, previous/current dog owners and non-dog owners or whether a person had been bitten by a dog or not.

5.3.2 Approach-stop distance

5.3.2.1 Task duration

There was no evidence of a difference in the duration (s) of tasks when categorised either by order of tasks (i.e. first (Md = 29.2s, IQR = 16.8 - 36.6), second task (Md = 26.7s, IQR = 18.4 - 43.6) (n = 18; Z = -0.501; p = 0.616)) or by coat colour (yellow (Md = 25.5s, IQR = 17.2 - 44.8) and black (Md = 28.4s, IQR = 20.5 – 32.4) (n = 18; Z = -0.849; p = 0.396)).

5.3.2.2 Total distance travelled

There was no evidence of an order effect in total distance travelled (first trial, Md = 6.8m; IQR = 5.8 – 8.9; second trial, Md = 7.0m; IQR = 6.0 – 10.5) (n = 18; Z = -1.024; p = 0.306). There was also no difference in total distance travelled between the two conditions (yellow, Md = 7.0m, IQR = 6.6 - 8.9; black coat, Md = 6.7m, IQR = 5.5 – 9.9) (n = 18; Z = -0.828; p = 0.408).

5.3.2.3 Closest proximity to the dog

There was no evidence of a difference between the closest proximity (based on head position at point of placing the handsets) an individual got to the dog based on the order of the tasks (first task, Md = 1.0 m, IQR = 0.8 – 1.5; second task, Md = 1.3m, IQR = 0.9 – 1.7) (n = 18, Z = -0.752; p = 0.452). There was no evidence of a significant difference in closest proximity to the dog model between coat colour conditions (black, Md = 0.9m, IQR = 0.7 – 1.6; yellow, Md = 1.4.m, IQR = 9.0 – 1.7) (n = 18, Z = -1.841; p = 0.066).

5.3.2.4 Closest distance to the dog and demographics.

There was no difference between gender, ethnicity, education level, previously bitten, previous VR experience and the closest distance a participant (head) got to the black and yellow dog (Table 5.1). However, in the black dog scenario, those who did not currently own dog moved closer to the dog compared to those who currently owned dogs. In addition, there was no correlation between participant age and the closest distance to the black (p = 0.119) or yellow (p = 0.330) dog (Table 5.1).

Table 5.1 Comparison between participant demographics and experience and median closest distance (metres) to the black and yellow dog model.

	Black dog			Yellow dog		
	Median dist.	**U**	**p-value**	**Median dist.**	**U**	**p-value**
Gender						
Male (n = 6)	0.7	19.500	0.180	1.1	23.000	0.350
Female (n = 11)	0.9			1.5		
Ethnicity						
White (n = 11)	1.3	22.500	0.151	1.3	34.500	0.724
Non-white (n = 7)	0.8			1.5		
Education						
AS level or lower (n = 13)	0.9	14.500	0.075	1.3	18.000	0.173
Degree or higher (n = 5)	1.7			1.7		
Dog ownership						
Yes, currently (n = 9)	1.5	18.000	**0.050**	1.5	35.000	0.666
Not currently (n = 9)	0.8			1.2		
Bitten						
Yes	0.9	30.000	0.849	1.0	25.000	0.503
No	1.2			1.5		
Prev. VR experience						
Yes	1.1	32.000	0.813	1.6	22.000	0.230
No	0.9			1.2		

5.3.2.5 Closest distance to the dog and personality traits

There was no correlation between closest distance a participant (measured as the head location on placement of the handsets) got to the black dog and all five of the personality (TIPI) traits (extraversion (r_s = -0.247; p = 0.322), agreeableness (r_s = -0.348; p = 0.157), conscientiousness (r_s = 0.389; p = 0.110), emotional stability (r_s = -0.130; p = 0.606) and openness (r_s = 0.293; p = 0.238)). There was a positive correlation between closest distance to the yellow dog and conscientiousness (r_s = 0.564; p = 0.015) (i.e. the further away the person stopped from the dog the higher the conscientiousness trait score). There was no correlation between the closest distance to the yellow dog and remaining four traits (extraversion (r_s = -0.195; p = 0.438), agreeableness (r_s = 0.129; p = 0.610), emotional stability (r_s = 0.085; p = 0.736) and openness (r_s = 0.301; p = 0.225)).

5.3.2.6 Level of aggression reached

The level of aggression participants stopped at in the black dog condition was level 6 (7), 7 (3), 8 (6), 9 (2) and the yellow dog was Level 1 (2), 2 (1), 6 (6), 7 (5), 8 (4). Of the two participants which only reached level 1, these both occurred on the first task with the yellow dog model.

5.3.2.7 Change in levels of aggression and approach speed

This was no difference in speed of approach pre and post level 5 change ($p = 0.236$) for the yellow dog (Figure 5.2). The speed of approach was significantly ($p<0.05$) slower post level 6 (ears back, direct eye contact, walking backwards) and 7 change (body crouched, ears back, tail tucked underneath the body with teeth showing) for both the yellow and black dogs (Figure 5.2 and 5.3). There was also a significant reduction in speed pre and post level 8 in the black dog. Statistical comparisons could not be conducted for level 8 in the yellow coat group and level 5 and 9 in black coat group as the Wilcoxon test requires a minimum sample of 6 (Santigli *et al*., 2017).

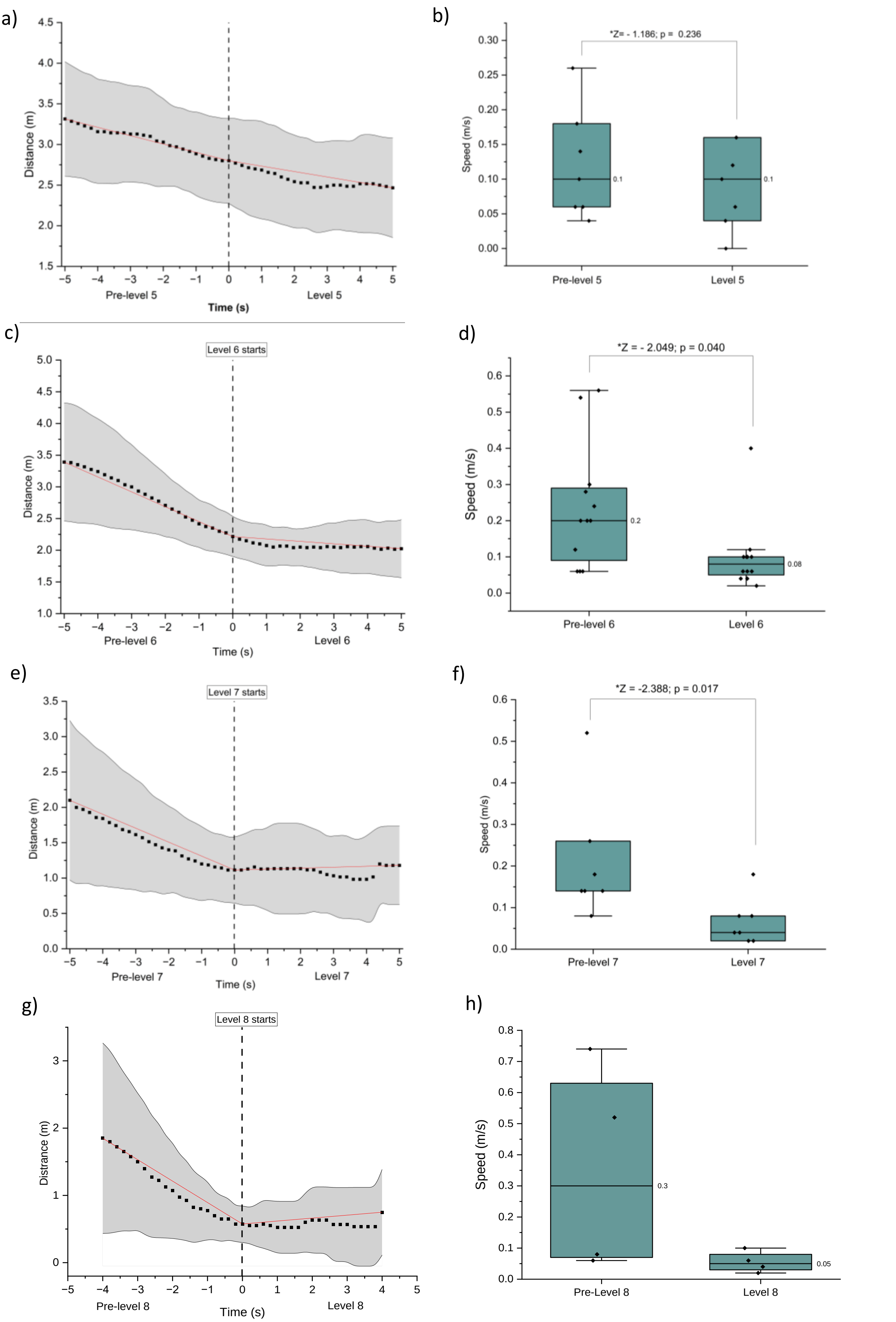


Figure 5.2 Mean distance per data point (black square) and standard deviation (grey) and linear piecewise function (red line) five seconds pre and post level 5, 6, 7 and 8 change (left) and median speed pre and post level 5, 6, 7 and 8 (right) in the task involving the yellow dog.

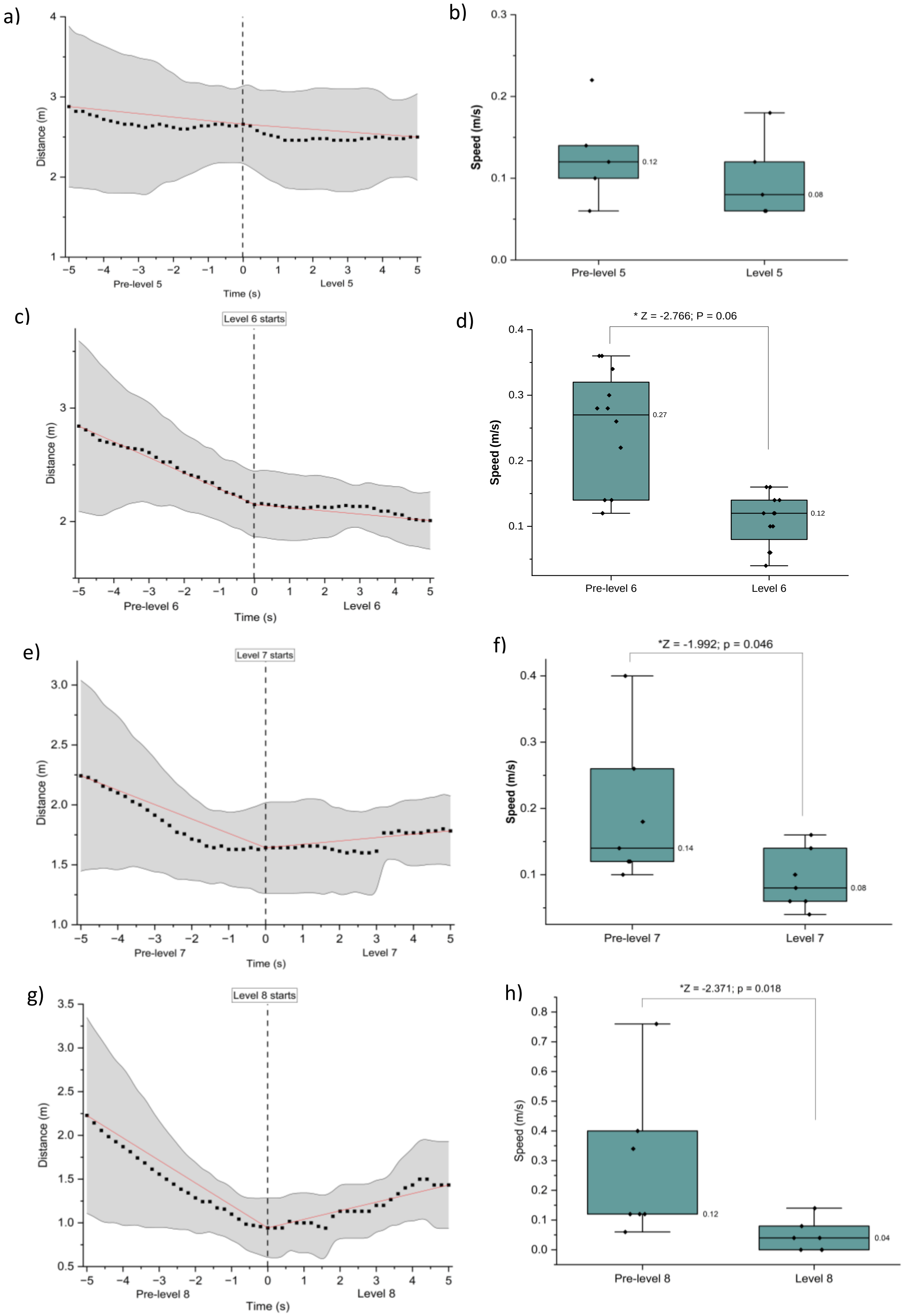


Figure 5.3 Mean distance per data point (black square) and standard deviation (grey) and linear piecewise function (red line) five seconds pre and post level 5, 6, 7 and 8 change (left) and median speed pre and post level 5, 6, 7 and 8 (right) in the task involving the black dog.

5.3.3 Heart rate

Ten participants had their heart rate monitored before and during task 1 and 2. Participants heart rate (bpm) was significantly higher in the first task (Md = 101.0 bpm) compared to the pre-task (baseline) (Md = 89.9 bpm, IQR = 82.1 – 101.3) (Z = -1.300, p = 0.004, r = 0.07) and the second task (Md = 93.9 bpm) (Z = 1.100, p = 0.014, r = 0.06). There was no evidence of a difference in heart rate between the pre-task and second task (p = 0.655) (Figure 5.4). When categorised by coat colour, irrespective of order, there was a significant increase in heart rate in the task involving the black coat (Md = 99.5 bpm; IQR = 84.2 - 111.0) compared to the pre task (Md = 89.9 bpm, IQR = 82.1 – 101.3) (Z = -2.395, p = 0.017, r = 0.12). There was no evidence of a difference in heart rate between pre-task and yellow coat (Md = 96.0 bpm, IQR = 93.1 – 109.5) (Z = -1.784, p = 0.074) or between the black and yellow coat (Z = -0.102; p = 0.919).

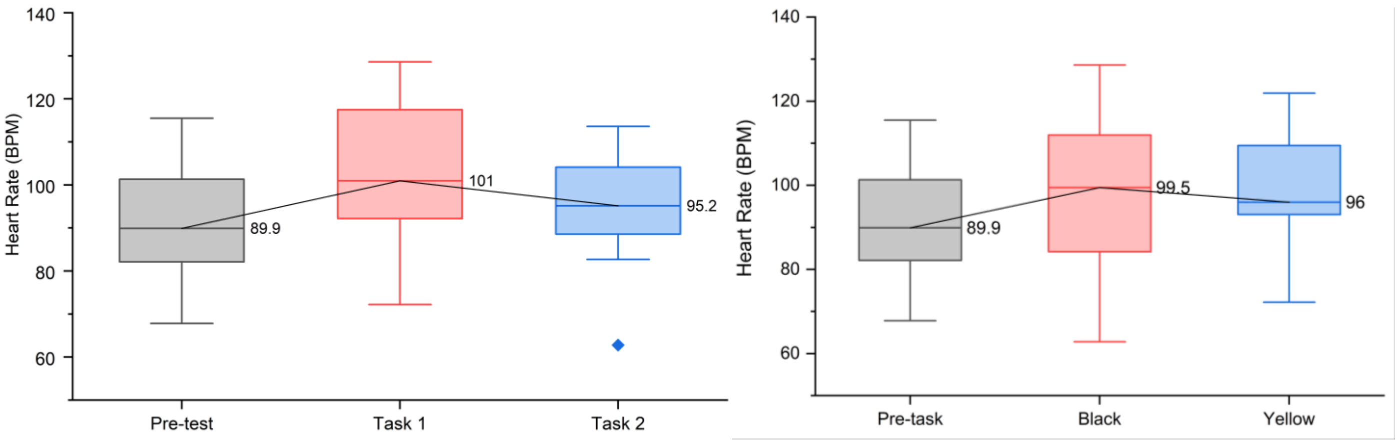


Figure 5.4 Whisker and boxplot displaying Heart rate (BPM) by pre-task, Task 1 and Task 2 (Left) and heart rate (BPM) by dog model coat colour (Right).

5.3.4 Dog behaviour recognition

The behaviour noticed by participants are shown in Table 5.2. Regarding behaviour interpretation when a dog was showing their teeth, it was deemed the dog was communicating it was a threat by 50% and 72% in the first and second task respectively. Prior behaviours more frequently were deemed to be ‘not a threat’. The lip lick and raising a paw was deemed as the dog communicating it wants to play by at least a quarter of participants (Table 5.3). Specific behaviour appeared to prompt specific interpretation such as paw raise (e.g. in pain) or yawn (e.g. tired) or licking lips (e.g. thirsty).

Table 5.2 Participants response as to whether or not they saw a specific behaviour during the two tasks (first trial is task 1, second trial is task 2).

		Lip Lick		**Yawn**		**Paw raise**		**Head turn**		**Backing away**		**Showing teeth**	
		n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Task 1	Yes	8	44.4	5	27.8	7	38.9	6	33.3	5	29.4	14	77.8
	No	10	55.6	13	72.2	11	61.1	12	66.7	12	70.6	4	22.2
	Total	18	100	18	100	18	100	18	100	17	100	18	100
Task 2	Yes	12	66.7	6	33.3	11	61.1	7	38.9	13	72.2	12	66.7
	No	6	33.3	12	66.7	7	38.9	11	61.1	5	27.8	6	33.3
	Total	18	100	18	100	18	100	18	100	18	100	18	100
Black	Yes	9	50.0	4	22.2	8	44.4	11	61.1	10	55.6	13	72.2
	No	9	50.0	14	77.8	10	55.6	7	38.9	8	44.4	5	27.8
	Total	18	100	18	100	18	100	18	100	18	100	18	100
Yellow	Yes	11	61.1	7	38.9	8	44.4	8	44.3	15	88.2	13	72.2
	No	7	38.9	11	61.1	10	55.6	10	55.6	2	11.8	5	27.8
	Total	18	100	18	100	18	100	18	100	17	100	18	100

5.3.5 Blame

The majority of participants thought that either themselves and/or the owner/caregiver were to blame for the dog's behaviour (Table 5.4). Only one and two participants blamed the dog in task 1 and 2 respectively. However, all 3 of these occurred in the scenario with the black dog.

5.3.6 Dog model realism

For both tasks the majority (83.3 - 100%) of participants agreed that the appearance, behaviour, vocalisations of the dog model were like that of a real dog. The majority also agreed that the environment was like that of the real world (77.8%) and user movement was like that of human movement (83.4 - 95%) (Appendix 5.3).

Table 5.3 Participants perceived meaning of specific behaviours (lip lick, yawn, raised paw, head turn, backing away and showing teeth), regardless of whether they saw the behaviour during the task (first trial is task 1, second trial is task 2).

	Lip Lick				**Yawn**				**Raise paw**				**Head turn**				**Backing away**				**Showing teeth**			
	Task 1		**Task 2**		**Task 1**		**Task 2**		**Task 1**		**Task 2**		**Task 1**		**Task 2**		**Task 1**		**Task 2**		**Task 1**		**Task 2**	
Behaviour	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
A threat	1	5.6	0	0	3	16.7	2	11.1	1	5.6	2	11.1	1	5.6	2	11.1	2	11.1	4	22.2	9	50.0	13	72.2
Defensive	1	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0	0
Dominant	1	5.6	0	0	0	0	0	0	1	5.6	2	11.1	0	0	2	11.1	1	5.6	0	0	6	33.3	4	22.2
In Pain	0	0	0	0	0	0	0	0	2	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nervous	0	0	0	0	0	0	0	0	1	5.6	0	0	0	0	0	0	0	0	1	5.6	0	0	0	0
Not a threat	4	22.2	4	22.2	3	16.7	3	16.7	5	27.8	8	44.4	11	61.1	8	44.4	6	33.3	10	55.6	0	0	0	0
Scared/afraid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11.1	0	0	1	5.6	0	0
Stressed	1	5.6	1	5.6	2	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thirsty/too warm	2	11.1	1	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tired	0	0	0	0	9	50.0	12	66.7	0	0	0	0	1	5.6	0	0	0	0	1	5.6	1	5.6	0	0
Wanting to play	4	22.2	3	16.7	0	0	0	0	6	33.3	4	22.2	0	0	4	22.2	0	0	0	0	1	5.6	0	0
Other*	0	0	1	5.6	0	0	0	0	0	0	1	5.6	1	5.6	1	5.6	3	16.7	2	11.1	0	0	0	0
I don’t know	4	22.2	8	44.4	1	5.6	1	5.6	2	11.1	1	5.6	4	22.2	1	5.6	4	22.2	0	0	0	0	1	5.6
Total	18	100	18	100	18	100	18	100	18	100	18	100	18	100	18	100	18	100	18	100	0	0	18	100

* Looking for owner/reassurance, uncomfortable, worried, watching you, I don’t remember

Table 5.4 Blame assigned for the dog's behaviour (multiple choice) categorised by scenario and order of tasks (n =18).

	Black		Yellow		1st Task		2nd Task	
Overall, who do you think is to blame for the dog behaving this way?	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Yourself (the person approaching the dog)	12	66.7	9	50.0	10	55.6	11	61.1
The owner/caregiver	6	33.3	10	55.6	6	33.3	10	55.6
No-one	2	11.1	0	0	1	5.6	1	5.6
The dog	3	16.6	0	0	1	5.6	2	11.1
I don't know	1	5.6	2	11.1	2	11.1	1	5.6

5.3.7 Presence

The mean general and spatial presence were received a relatively high rating ranging from 4.4. to 4.7 out of 6.0 (Table 5.5).

Table 5.5 Mean and median scores for presence

	Task 1		Task 2	
	Mean	**Median**	**Mean**	**Median**
General Presence	4.7	5.0	4.7	5.0
Spatial presence	4.4	5.0	4.5	5.0
Involvement	3.9	4.0	3.9	4.0
Experienced realism	3.0	3.0	3.2	4.0

5.4 Discussion

5.4.1 Coat colour

The aim of this study was to explore the effect of dog coat colour on approach stop distance in a virtual environment. Interestingly this study found that there was no evidence of a difference between coat colour and task duration, total distance travelled or closest distance to the dog model. Therefore, in the present study there was no evidence of coat colour alone having a significant effect on participant behaviours around a dog model displaying aggressive behaviour. The perception of the dog is also likely to be influenced by other morphological characteristics (e.g., body size, skull shape). This is an area that requires further research through the development of the dog model.

While none of the demographic variables (gender, age, education level) revealed any differences in response to the dog model in relation to two different coat colours, the personality trait 'conscientiousness' showed a moderate correlation with the closest distance a participant got to the yellow dog but not the black dog. This result suggests that the more conscientious participants were the more cautious they were, and they kept a larger distance between themselves and the yellow dog. While some human personality traits have been linked to the treatment of animals (e.g. agreeableness linked to compassion for animals) (Hopwood *et al.*, 2023), the only two studies, to the authors knowledge, that explored human personality traits in relation to interactions with dogs did not find any significant links between conscientiousness and human-dog interactions (Davis *et al.,* 2012; Westgarth *et al.,* 2018).

5.4.2 Personality

This study found a positive correlation between the personality trait conscientiousness and the distance an individual got to the dog. Previous research has found similar findings (a positive correlation between consciousness and distance from the robot) in research relating to human-robot interactions (i.e. asking an individual to approach a robot to read instructions) (Lehmann *et al*., 2020). Although recently, Powell *et al*. (2021) suggest that it is possible that the personality trait conscientiousness "*may influence how an owner perceives their dog's behavior and the severity of the behavioral problem*" Chopik *et al*. (2019) also found that owners that were higher in conscientiousness rated their own dogs as less fearful and less aggressive towards both people and animals. However, the majority of research focuses on owners with their own dog and it remains unclear if individual personality, attachment or interaction style also influences human distance or approach or avoidance behaviour in the presence of an unfamiliar dog. Also see Chapter 9 for further discussion regarding the use of the TIPI and the Big Five model.

5.4.3 Dog experience

Regarding dog related experience, the only difference observed between the two tasks was linked to current dog ownership, where participants who did not currently own a dog moved closer to the black dog in comparison to those who did own a dog. The effects of current dog ownership status on perceptions of behaviour may benefit from further research to understand the possible implications for safety around a dog displaying aggressive behaviour.

5.4.4 Level of aggression reached and speed of approach

In contrast to the hypothesis of the Black Dog Syndrome theory, two participants reached level 9 (lunge and snap) in the black dog scenario, but no participants reached level 9 in the yellow dog scenario. All participants who approached the black dog model reached level 6 (ears back and moves backwards) or higher, whereas 15 out of 18 participants reached level 6 or higher in the yellow dog scenario. This may suggest that the participants were more cautious of the yellow dog model, but it is also possible that the black coat colour made recognising more subtle behaviour changes i.e. ear movements or jaw clenching, more challenging due to low contrast between dog body parts so the ear position may have been less easy to see. However, see below regarding speed of approach.

Reassuringly as the dog models' avoidance behaviours became increasingly obvious (levels 6 and upwards), participants did slow their approach towards the dog, under both colour conditions, when comparing five seconds before and after the behaviours changed aggression levels (escalating up the CLA). This indicates that the changes in dog behaviour had an impact on participant behaviour in a way that suggests a more cautious approach. However, this slower approach only occurred in relation to the more obvious behaviours whilst subtle behaviours (i.e. Level 5; lip lick, yawning) appeared to not result in the same degree of caution. This could simply be due to individuals associating more obvious behaviours with aggression, as found in previous research (Mariti *et al*., 2012; Jacobs *et al*., 2017).

5.4.5 Heart rate

The recorded heart rate increased from baseline line to the first and second task regardless of coat colour, which could be explained by the difference in activity levels between baseline (sitting) and tasks (walking). These results need to be interpreted with caution given the small sample and effect sizes due to the optional participation.

The use of the Polar H10 heart rate monitor has been previously validated and was able to be recorded with ease via Bluetooth on a mobile phone application. However, the recording of VR tracking and Heart Rate output were recorded independently from one another. Although every effort was made to synchronise the timings. In future research it would be more practical for the VR system and heart rate monitor to be combined so all measurements are recorded at the start of the VR task and in a single data output format. An additional limitation of the heart rate monitoring for the baseline recording was monitored for a one-minute period and the subsequent VR tasks were monitored based on the length of the task determined by each participant and therefore as found in this study can range from 9.7 to 122 seconds. A more controlled approach with a minimum task time (e.g., as per Chapter 4) could be applied to allow a consistent HR comparison. Only 10 out of 18 participants took part in the HR monitoring part of the task. Further uptake of such intervention may have been higher if an easier or less intrusive method of wearing the monitor was available (e.g. wrist monitor). However, chest straps have been found to give more accurate results compared to wrist worn HR devices (Wang *et al*., 2017; Pasadyn *et al*., 2019).

5.4.6 Blame

The blame for the dog behaviours was consistent with prior research, indicating that the majority of blame is perceived to fall on the humans (i.e. themselves or the owner) rather than the dog (Westgarth and Watkins, 2015). There was, however, some evidence people blamed the black dog more than the yellow, supporting the Black Dog Syndrome theory.

5.4.7 Limitations

In the present study the sample size was small. It would be useful for future studies to use a larger sample size and consider the low turnout rate to practical sessions by over recruiting.

Regarding the practical sessions, the instruction to place the handsets down on the floor could have been clearer. It was clear that participants moved closer to the dog then moved back to place the handsets down. More strict instructions could be provided going forward. Having said this, the measurement of the closest distance versus the placement of the headsets may allow for the perceived versus actual proximity to the dog model to be compared, which may shed light on differences between real-life behaviour and participant conscious responses that may be subject to confirmation bias.

Further areas of research could explore other measures not covered in the present study such as skin conductance which has been previously used in the exploration of proxemics to virtual characters and found the closer virtual characters got the increased in user arousal was recorded (Llobera *et al*., 2010).

5.5 Conclusion

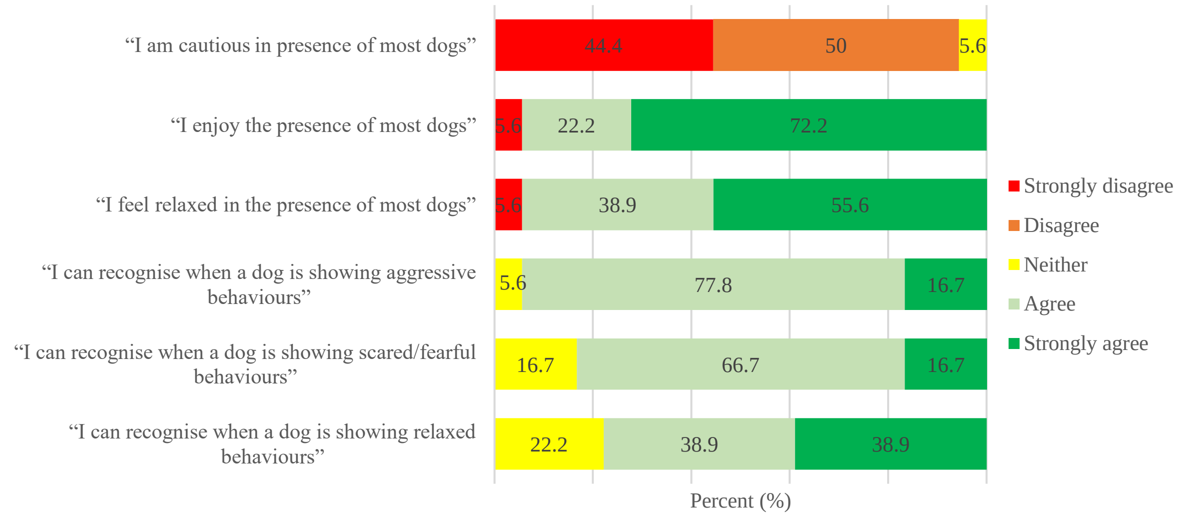
In conclusion, this study appears to mostly agree with other studies arguing against the existence of 'black dog syndrome' (Diesel *et al*., 2008; Brown *et al*., 2013; Svoboda and Hoffman, 2015; Nakamura *et al*., 2020; Trevathan-Minnis *et al*., 2021). However, dog ownership status and personality traits appeared to influence the closest distance participants got to the black and yellow dog models respectively. Furthermore, there was some evidence to indicate that participants may be more likely to assign blame for the dog's behaviour to the black dog model, more so than the yellow dog model. Future research should seek to further explore these traits and involve development of the VR model to consider additional morphological traits.

APPENDICES FOR CHAPTER 5

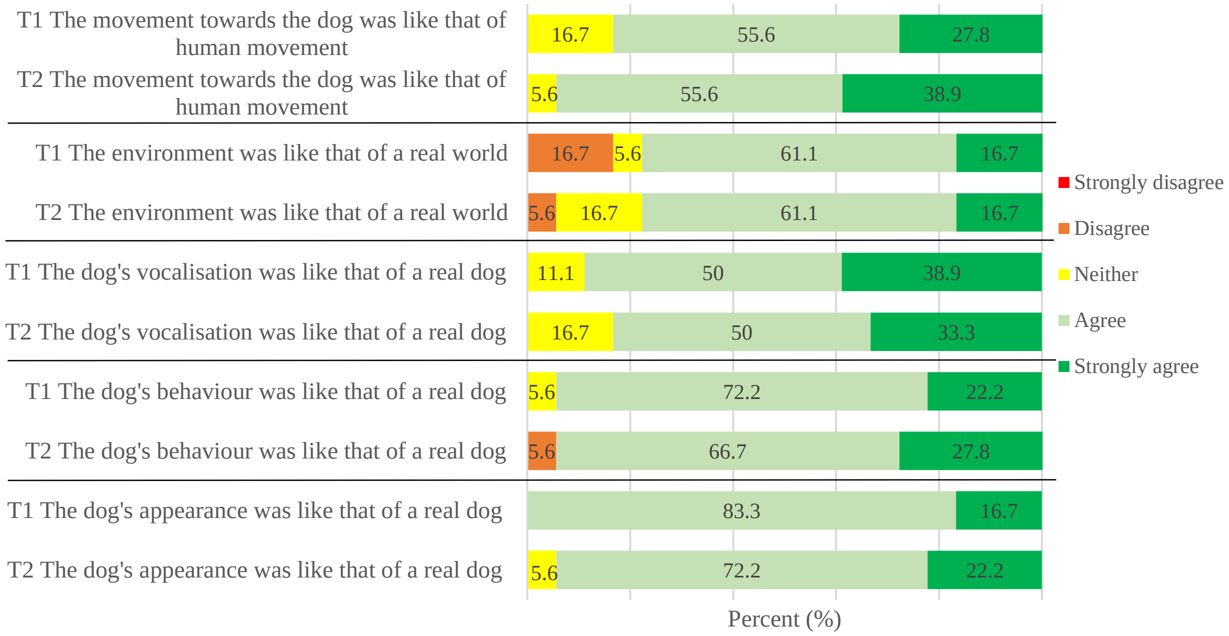
Appendix 5.1 Participant demographics (n = 18).

Demographic	n	%
Age - mean (range)	21.8 (18 - 35)	
Sex		
Male	6	33.3
Female	11	61.1
Other	1	5.6
Ethnicity		
White	11	61.1
Asian / Asian British	4	22.2
Other	2	11.1
Prefer not to say	1	5.6
Highest qualification		
A/AS level	11	61.1
First degree level qualification including foundation degrees, graduate, membership of a professional Institute, PGCE	1	5.6
University Higher Degree (e.g. MSc, PhD)	5	27.8
None of the above	1	5.6
Previous experience with VR		
Yes	10	55.6
No	7	38.9
Not sure/can't remember	1	5.6
Dog ownership		
Yes, I currently own a dog	9	50
Yes, previously owned a dog but not currently	5	27.8
No, not currently and not previously owned a dog	4	22.2
If Yes, to current/previous dog ownership (n = 14)		
Less than 1 year	2	14.3
between 1 year but less than 3 years	0	0
between 3 years but less than 5 years	3	21.4
between 5 years but less than 7 years	0	0
between 7 years but less than 9 years	3	21.4
9 years or longer	6	42.9
Bitten (causing at least bruising or puncture to the skin)		
Yes	5	27.8
No	13	72.2
Currently in a job with contact with dogs		
Yes	1	5.6
No	17	94.4

Appendix 5.2 Six statements relating to the feelings in the presence of dogs and self-reported ability to interpret dog behaviour (n = 18).



Appendix 5.3 Agreement to statements relating to the appearance, behaviour vocalisation, environment, and human movement in VR in comparison to the real world. (T1 = Task 1; T2 = Task 2)



CHAPTER 6. AN ONLINE UK SURVEY ASSESSING THE RECOGNITION AND INTERPRETATION OF CANINE BEHAVIOURS INDICATIVE OF DEFENSIVE AGGRESSION USING A VIDEO OF A SIMULATED DOG WITH AND WITHOUT AUDIO

6.1 Introduction

Due to the historical human-dog relationship and intense selection pressures, during and since domestication, dogs have adapted socio-cognitive abilities which allow them to effectively communicate with humans whilst largely retaining their species-specific behavioural repertoire (Bowen and Heath, 2005). However, research has demonstrated that dogs have a unique ability to understand a range of human behaviours, gestures and emotions (Kaminski and Nitzschner, 2013; Albuquerque *et al.,* 2016; D'Aniello *et al*., 2016; Ferretti and Papaleo, 2019; Benz-Schwarzburg *et al*., 2020; Albuquerque *et al*., 2022). In contrast, the same cannot be said for human interpretation of dog visual signals/behaviours and emotions, as these interpretive abilities do not extend to the same degree. For example, dog bites, which are increasing in the UK (Tulloch *et al*., 2021), are often described as 'out of context', 'out of nowhere', 'unprovoked' or 'occurring without warning' (Love and Overall, 2001; O'Sullivan *et al*., 2008; Hecht and Horowitz, 2015). But these descriptions are often inaccurate and are likely due to a lack of recognition, interpretation, and/or education of the relevant dog behaviours. The likelihood is that prior to a bite incident, a dog displays some form of behaviour communicating its current emotional state (e.g. as per Shepherd's (2009) CLA model (see Chapter 1.3)).

Human treatment and interpretation of dogs displaying aggressive behaviour could be anthropomorphised, potentially resulting in humans displaying inappropriate or risky behaviour towards a dog (e.g. hugging, bending over the dog, holding direct eye contact) whilst being unaware of how their behaviours are being perceived by the dog (Mills *et al*., 2014; Arluke *et al*., 2018). For example, Rezac *et al*. (2015) found that a common circumstance in which dog bite injuries to the face occurred was whilst a human was either bending over and/or putting their face near the dogs face. Similarly, Reisner and Shofer (2008) surveyed 804 dog owners about child-dog interactions and the majority of owners (82%) stated that they deemed it safe to permit children to hug and kiss a family dog. In addition, human interpretation of dog behaviour could simply be inaccurate due to misunderstandings about the dog's motivation for the behaviour (e.g. aggression towards humans may be seen as the dog seeking dominance rather than because of fear (Reisner and Shofer, 2008)) or being unaware of the behaviours and their meanings. For instance, Meints *et al*. (2010) found that pictures of a dog snarling and exposing its teeth were frequently mistaken as being friendly and smiling by 69% and 35% of four and five-year-old children, respectively (also see Meints *et al*., 2018). An individual's ability to recognise aggressive or fearful behaviours has been found to be influenced by multiple human factors, e.g. age (Meints *et al*., 2010; Meints *et al*., 2018; Eretová *et al*., 2020), cultural attitude towards and experience with dogs (Wan *et al*., 2012; Bloom and Friedman, 2013; Demirbas *et al*., 2016; Amici *et al*., 2019).

Meints *et al*. (2018) found that young children often misinterpreted videos of dogs displaying distress signals and vocalisations, including growling, did not aid in their interpretation of signals. In contrast, research indicates that adults are relatively accurate at interpreting and classifying dog vocalisations (Siniscalchi *et al*., 2018; Oláh *et al*., 2021) e.g. growling (Faragó *et al*., 2017), barking (Pongrácz *et al*., 2005).

Having said this, given the accuracy of dog vocal interpretation by adults, the use of vocalisation in conjunction with behaviours is potentially beneficial to support the accurate interpretation of dog behaviour by humans. Studies designed to measure the accuracy of human raters interpreting dog behaviour should therefore include both auditory and visual cues, to be both realistic and valid measures of these complex behaviours.

Videos can be engaging and communicate detailed information such as the display of a full dog behaviour signal rather than a single image, whilst also potentially providing the context in which the behaviour occurs. To date, most of the dog bite-related research uses videos of real dogs to investigate participants' ability to identify or interpret fearful and/or aggressive dog behaviours or emotions (Lakestani *et al.,* 2015; Meints *et al*., 2018; Aldridge and Rose, 2019; Eretová *et al*., 2020), observe human and dog behaviour prior to a bite (Owczarczak-Garstecka *et al*., 2018), hazard perception test of dog bite hazards (Christley *et al*., 2021), and deliver dog bite safety and prevention education interventions (Shen *et al*., 2017; Meints *et al*., 2018). However, studies using videos displaying fearful and aggressive dog behaviour often use a variety of short pre-existing (i.e. not specifically obtained for the study) video clips, which may vary in visual and audio quality, angles from which the dog is filmed, and distance from the dog. They may use different breeds/conformation/sizes/colours of dogs for each video and display specific individual behaviours rather than the suite of behaviours that may lead to a dangerous outcome (e.g. as with the CLA).

To overcome the latter difficulties, virtual reality enables full control over a virtual environment and its content (i.e., a VR dog). Furthermore, videos of a virtual dog model allow for multiple behaviours to be developed and shown in a single video and a consistent approach (camera angle, quality, virtual agent, etc.) across multiple videos. This may also be beneficial in circumstances where virtual reality or live dogs cannot be utilised (i.e., face-to-face research during COVID-19) and videos are required or maybe cost-effective (i.e., a national or international survey). A survey of self-reporting dog bite victims found that 46% of participants stated that they approached the dog just before the bite occurred (Oxley *et al*., 2018). Furthermore, Aldridge and Rose (2019) found that 81% of children would approach a frightened dog based on images and video clips. However, limited research has been conducted on the proximity of individuals toward an aggressive dog, most likely due to ethical and safety concerns. Therefore, this study aimed to: i) Assess the participants' perceived safest proximity to approaching an aggressive and non-reactive simulated dog; ii) Compare the effects of using videos, which includes a single video of a simulated dog, a Labrador, displaying an array of behaviours, with and without audio to determine if this affects participant proximity to the aggressive and non-reactive dog; iii) Assess the relationship between proximity to aggressive and non-reactive dogs and demographics (age, gender, education), personality and participants prior dog-related experience; iv) Assess participants' recognition and interpretation of aggressive dog behaviours; and v) measure participants presence as a result of a video task.

6.2 Method

6.2.1 Participants

6.2.1.1 Recruitment

An online survey, hosted in Gorilla experimental builder online software (Anwyl-Irvine *et al*., 2020), was distributed through social media applications, including Facebook, Facebook groups, LinkedIn and Twitter, between November and December 2020. This included a brief description and poster, with a link to the survey, requesting both dog owners and non-dog owners to complete an online survey about the assessment of dog behaviour and human behaviour around dogs. The survey was open to all adults that currently lived in the UK who were 18 years of age or older.

6.2.1.2 Sample size

A total of 683 responses were received. However, 34 participants were automatically rejected after the first section of the survey due to participants answering 'Yes' to the question, "*Are you currently scared, fearful or have a phobia of most dogs?*". Additionally, 90 participants were removed because they could not play at least one of the five videos (57) or completed less than 50% of the questionnaire (33). This resulted in a final sample of 559.

6.2.2 Ethics

This study was approved by the University of Liverpool Veterinary Research Ethics Committee (Ref. VREC992) and conducted in compliance with the Declaration of Helsinki. At the start of the questionnaire, an information page detailed the purpose of the study, ethical approval information, that no personal details would be collected, participation was voluntary and contact information. All participants were required to consent to take part, following reviewing the survey participant information sheet.

6.2.3 Online survey

An online survey was developed to assess adult proximity to a dog and recognition of aggressive behaviours in a virtual environment using videos. A draft was developed, tested, and then piloted on eight people, including a veterinarian, a veterinary nurse, a canine behaviourist, dog owners and non-dog owners. Participant feedback was incorporated into the final survey.

The final survey was split into four sections. Section one included questions relating to participant demographics (age group, gender, education level), personality traits (Ten Item Personality Inventory (Gosling *et al*., 2003)) and dog-related experience (previous/current dog ownership, length of ownership, frequency of close contact with dogs, dog-related work/hobbies). Participants were asked if they had previously been bitten by a dog (defined as "*causing at least a bruising or skin puncture*" (Oxley *et al*., 2019, p. 43)). Furthermore, participants were asked for their agreement on ten dog statements, seven related to the comfort level in the presence or in anticipation of dogs (four were from the Dog Phobia Questionnaire (q1, q3, q5, q26) (Vorstenbosch *et al*., 2012)) and three related to respondents own perceived ability to recognise aggressive, fearful, and relaxed dog behaviours. A screening question, "*Are you currently scared, fearful or have a phobia of MOST dogs?*" was included and if answered 'yes', the survey finished. If they answered 'No' or 'I don't know', they proceeded to section 2. All questions, apart from how long an individual owned a dog, were compulsory for this section.

Section 2 consisted of four tasks per participant, presented in a randomised order. Four videos were developed displaying an indoor environment resembling a living room (see Chapter 3). These videos were based on the pre-developed virtual dog model DAVE developed by the Virtual Engineering Centre, Daresbury, UK. The videos included a nonreactive dog model with and without audio (i.e., environmental sounds and dog vocalisations (panting, sniffing)) and an aggressive dog with and without audio. See Appendix 6.1 for the breakdown of the behaviours and levels in the aggressive video.

In each video, a camera approached the virtual dog model starting at 5m metres from the centre of the dog and approached until it was 0.6m away from the closest point to the dog (i.e. the dog’s nose), stopping before the dog would typically lunge and bite at ≤0.5m due to any potential participant distress. A four-second countdown occurred before the start of each video. The speed of the approach was the same in both the aggressive and non-reactive scenarios (Table 6.1). The videos were intended to imitate a person's approach; however, to keep the virtual camera's angles at a consistent level from start to finish, a height of 0.8 metres from the floor was used. This was also due to the difference in position between the non-reactive scenario and the aggressive scenario, as the aggressive dog moved backwards 0.5m from the starting position. This facilitated a consistent view of the dog throughout both videos. For each video, participants were asked to “*Press stop at the point you would, if you would stop, approaching the dog*”.

Table 6.1 Details of the approach-stop task videos

	Non-reactive Scenario	Aggressive Scenario
Video length	48.6 seconds*	56.5 seconds*
Closest distance to the dog	0.6 m (60cm)	0.6 m (60cm)
Speed of approach	0.07m/s	0.07m/s
Distance travelled from start to finish of the video	3.7 metres	4.2 metres

*Excluding a four-second countdown showing the title page only.

In section 3, participants were asked to watch the entire single video of the aggressive dog with sound. Questions related to the perceived emotion of the dog and asked participants in two open-ended questions to describe what they noticed about the behaviour of the dog in general and what this indicated about the dog. Additional closed-ended questions asked did they notice specific behaviours (including the lick lip, paw raise, head turn, backing away and showing its teeth). Further open-ended questions asked what participants thought these behaviours meant.

Section 4 contained the Igroup Presence Questionnaire (Schubert *et al.*, 2001) consisting of fourteen questions to determine the self-reported sense of presence (i.e., “being there”) in the virtual environment. Upon completing the survey, a debrief provided information about the study and contact information. (see surveys here: https://tinyurl.com/JOxleyPhD Digital).

6.2.4 Data Analysis

Demographics and dog-related experience were described, including the number of respondents and percentages per categorical variable. A chi-square test followed by univariable and multivariable logistic regression was conducted to examine demographic factors associated with if a person had previously been bitten. The inclusion of variables in the multivariable model required a *p*-value of ≤0.250. Finally, a stepwise backwards elimination was conducted where non-significant values were excluded until all remaining values included in the model were significant ($p<0.05$). A Hosmer-Lemeshow test was conducted to test the model's goodness of fit.

A Principal Component Analysis with varimax rotation was conducted on the ten statements about an individual's views and perceptions about dogs and their behaviour (Table 3). To ensure this test was suitable, a Kaiser-Meyer-Olkin measure of sampling adequacy was above 0.6 ($p = 0.773$), eigenvalues were above one and Bartlett's test was significant ($p = 0.000$) and therefore, this test was deemed suitable (Pallant, 2016). Loading values of more than 0.3 to be included in the analysis (Pallant, 2016).

In the approach-stop task, participants were asked to stop when they felt they were at a comfortable distance from the dog. Each participant's time they pressed stop was recorded. If participants did not press stop, they were recorded as the full-time (e.g., Aggressive 56.5s / Non-reactive 48.6s). Normality testing (including both Kolmogorov-Smirnov and logarithmic transformation) was conducted for approach stop times for each of the four videos; both were significant, indicating non-normal distribution. Therefore, to compare the stopping time across the four videos (i.e. repeated measures), a Friedman test two-way analysis of variance was conducted followed by mutiple Wilcoxon signed-rank test as a post hoc pairwise tests with a revised p value based on the number of comparison made ($p = 0.05/4 = 0.125$) (Pallant, 2016).

A Mann-Whitney U test was conducted to compare approach-stop times between categorical demographics and dog-related experience. A Kruskal-Wallis test was followed by a Mann Whitney U test for multiple comparisons. A multiple linear regression model with backwards stepwise elimination was performed to predict the approach-stop time for aggression (with sound) video and aggression (with no sound) from respondent's demographic and dog related experience. A Spearman rho was used to test for a relationship between personality subscales scores and approach-stop times.

The management and analysis of data were conducted in Microsoft Excel and IBM SPSS Statistics 27 (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp). Boxplots were created in Origin pro (OriginLab Corporation, Northampton, MA, USA).

6.3 Results

6.3.1 Demographics and dog-related experience.

Most respondents were female (84.7%), aged between 18 and 49 (71.3%), had a higher educational qualification (72.4%), either currently or previously owned dog(s) (77.1%), but did not work with dogs (74.8%) or have a hobby with dogs (80.1%) (Appendix 6.2). Over half (56.5%) stated that their average frequency of contact with dogs was at least once a day or several times a week. The majority stated that they could accurately recognise dog behaviours relating to fear and aggression (Figure 6.1)

Just under half (48.5%; 271) reported having been previously bitten by a dog resulting in a bruise or puncture to the skin. Univariable analysis indicated that participants aged 40 or over compared to those aged 18 – 39, currently or previously owned dogs, had a HE or equivalent qualification compared to School and further education (GCSE/CSE/O Level, AS/A Levels or equivalent, came into contact with dogs more often (once or at least once a day/or several times a week compared to several times a month/ once a month/ never), had a job with dogs and/or a dog-related hobby were significantly more likely to report to have been bitten (Appendix 6.3). However, there was no evidence of a difference in the likelihood of being bitten based on gender or personality traits. A multivariable model indicated that those aged 40 or over who had previously/currently owned dogs and previously had a job with a dog were more likely to have reported being previously bitten by a dog (Table 6.2). The final model was an appropriate fit (Hosmer-Lemeshow goodness of fit $\chi^2 = 3.532$; df = 6; p = 0.740).

A Principal Component Analysis of the ten statements about an individual's views and perceptions about dogs and their behaviour (Table 6.3) revealed three components (see scree plot in Appendix 6.4) PC1 (q1, q3, q4, q5, q6), PC2 (q8, q9, q10) and PC3 (q2, q7) all of which had a loading of ≥0.4 for at least one of the components. The three components accounted for 71.1% of the cumulative variance. A separate Cronbach alpha was conducted for each component to test for internal consistency resulting in acceptable (α = >0.7 (Pallant, 2016, p. 104)) reliability for PC1 ($\alpha = 0.888$) and PC3 ($\alpha = 0.779$). However, PC2 had low reliability ($\alpha = 0.240$) and the removal of q3 resulted in strong internal consistency ($\alpha = 0.795$) of PC2. Therefore, the final three components consisted of nine questions and had good sampling adequacy (KMO = 0.739); Bartlett's test of sphericity (p<0.001) and accounted for 74.0% of the cumulative variance (Table 6.3).

Table 6.2 The final multivariable model predicts the likelihood of reporting to have been previously bitten by a dog.

	OR	CI 95%	p-value
Age group			
18 – 39	1		
40 – 60+	1.637	1.103 -2.431	**0.015**
Previous/current dog Ownership			
No	1		
Yes - <9 years	2.746	1.552-4.857	**0.001**
Yes - ≥9years	4.825	2.813-8.277	**<0.001**
Previous job with dogs			
No	1		
Yes	3.483	2.231 – 5.436	**<0.001**

6.3.2 Approach-stop task

A Friedman test indicated evidence of a difference ($\chi^2(3) = 489.571$; p<0.001) in stopping time across the four video tasks. A Wilcoxon signed-rank test found participants got significantly closer to non-reactive (sound) (Md = 45.2s) than the aggressive (sound) (Md = 25.0s) dog (p<0.001; r = 0.45), non-reactive (no sound) (Md = 46.3s) than the aggressive (no sound) (Md = 24.1s) (p<0.001; r = 0.5) and non-reactive without sound (Md = 46.3s) than the non-reactive with sound (median = 45.2s) (p<0.001; r = 0.12) but not between the aggressive with sound (Md = 25.0s) and the aggressive without sound (Md = 24.1s) (p = 0.248) (Figure 6.2). Over half of the participants stopped at level one (Figure 6.3) in the aggressive videos, both with and without sound. See Figure 6.4 for a breakdown of the dog behaviours for participants who stopped in level 1. There was evidence of weak positive correlations between extroversion (personality) and time participants stopped in the aggressive video with sound (rho = 0.122, n = 559, p = 0.004), aggressive video without sound (rho = 0.132, n = 559, p = 0.002) and non-reactive video with no sound (rho = 0.090, n = 559, p = 0.034) (Appendix 6.5). There was no evidence of a difference in extroversion score between males and females (U = 17879.5; p = 0.215) or if a participant had been previously bitten by a dog or not (U = 25590; p = 0.635). There was no evidence of correlation between each of the three principal components, based on the ten statements, and the approach stop times for each video.

Figure 6.1 Ten statements relating to comfort and perceived dog behaviour recognition (n=559). (Note: values <1% are not displayed)

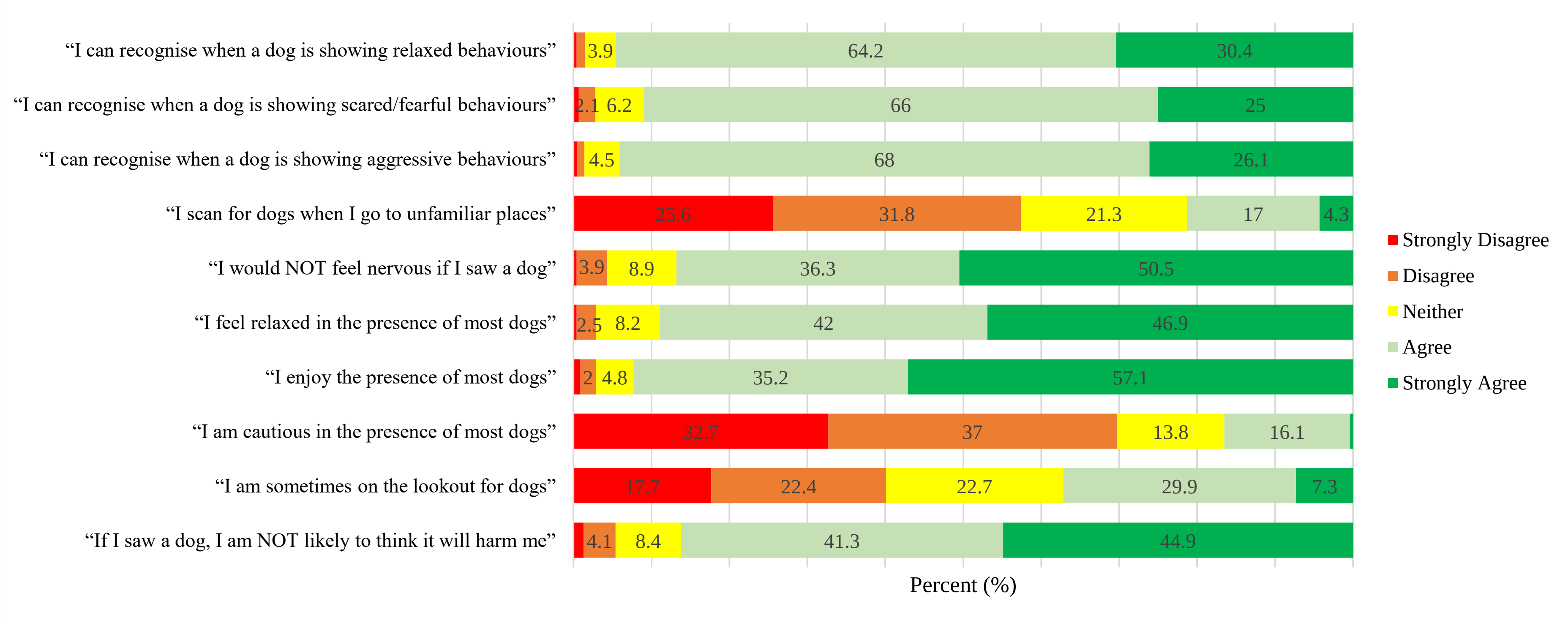


Table 6.3 Principal Component Analysis (Varimax with Kaiser normalisation) of nine dog-related statements (n = 559). Principal component 1-3 (PC1, PC2, PC3) and item variance/communalities (H^2). Q3 was removed due to the low Cronbach alpha value.

	Component			
	PC1 Presence of dogs	**PC2 Behaviour recognition**	**PC3 Surveillance/ observation**	**H^2**
q5	**0.859**	0.250	0.003	0.800
q6	**0.805**	0.145	-0.086	0.677
q4	**0.800**	0.154	0.058	0.667
q1	**0.632**	0.041	-0.189	0.437
q8	0.139	**0.919**	-0.035	0.865
q9	0.142	**0.909**	0.004	0.846
q10	0.216	**0.836**	-0.041	0.747
q2	-0.068	-0.018	**0.898**	0.811
q7	-0.079	-0.034	**0.897**	0.811

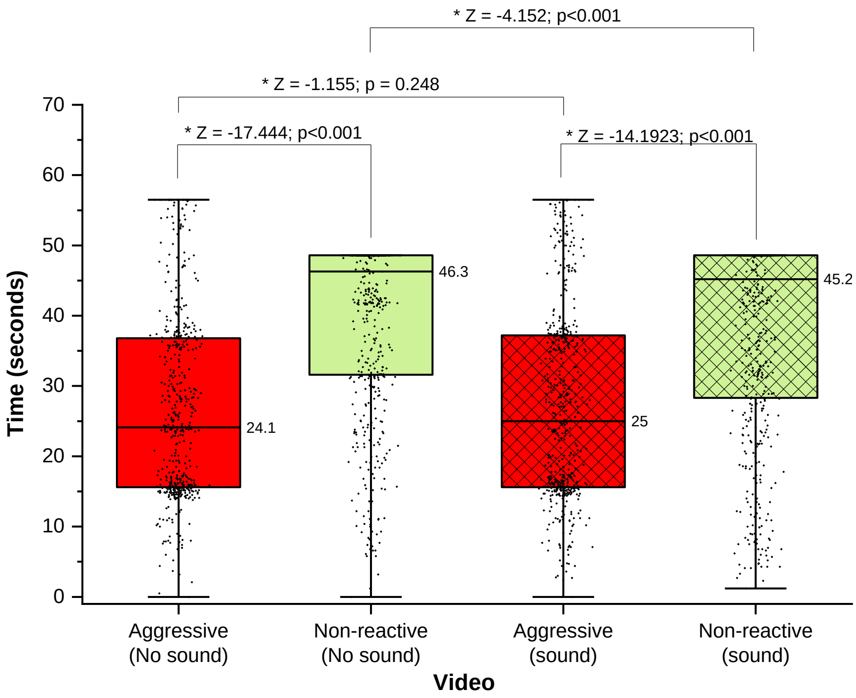


Figure 6.2 Box and whisker plot displaying the minimum, median and maximum duration (seconds) participants (n = 559) watched the video before pressing stop. (Note: those who did not press stop were given the maximum time for the condition (e.g., Non-reactive: 48.6s; Aggressive: 56.5s)).

Males and respondents that did not own, work with dogs, have a hobby with dogs, or had not been bitten by a dog got significantly closer to the aggressive dog model (Table 6.4). Those aged 30 – 39 more frequently stayed significantly further away from the aggressive dog compared to other age groups (Table 6.5).

The multivariable regression model indicated that all variables significantly predicted the approach-stop time towards the aggressive dog (with sound), including gender, age (18-39, 40->60), education level, previous/current dog ownership, hobby, dog-related job, contact with dogs (at least once a week/several times a week, several times a month/once a month/never) ($F(7, 526) = 0.031$; $p<0.001$; $R^2 = 0.107$). However, it only explained 10.7% of the variance in approach-stop distance. The Aggressive (no sound) model also identified variables that predicted approach-stop time ($F(5, 528) = 9.339$; $p<0.001$; rho = 0.081), including gender, age (18-39,40->60), education, previously bitten, dog-related job. However, this model only contributed to 8.1% of the variance in approach-stop distance.

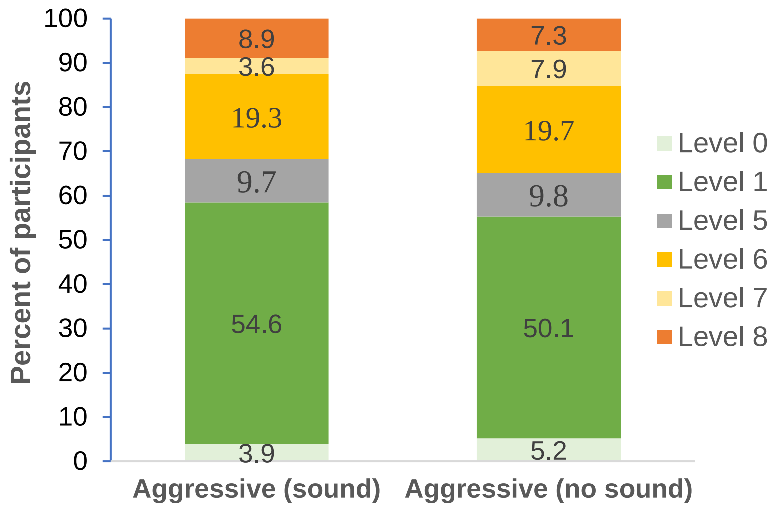


Figure 6.3 The percentage of participants (n=599) that pressed stop at each level of aggression for both the aggressive dog videos with sound and without sound (0-8)

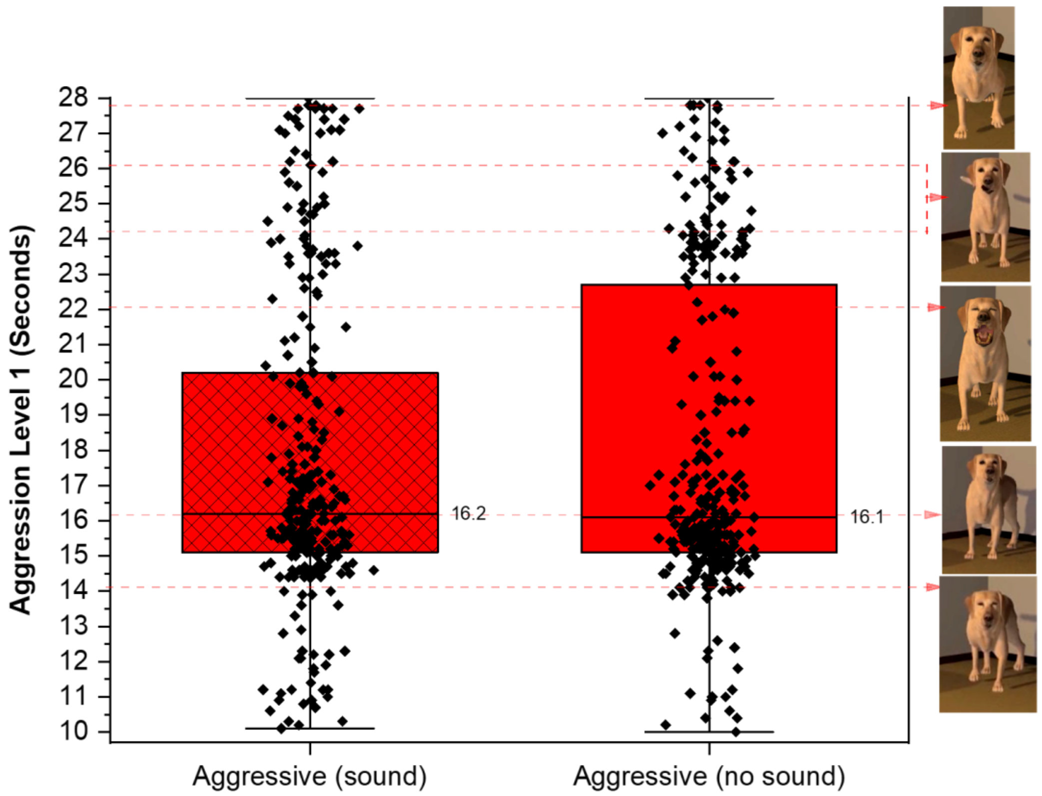


Figure 6.4 The time(s) participants stopped during Level 1 during the aggressive video with sound (n = 280) and the aggressive video without sound (n = 305) and the dog behaviours displayed during Level 1 of the video.

Table 6.4 Univariable analysis of demographics and median distance travelled in the four videos.

	Aggressive (no sound)		Non-reactive (no sound)		Aggressive (sound)		Non-reactive (sound)	
	Median time (s)	**p-value**	**Median time (s)**	**p-value**	**Median time (s)**	**p-value**	**Median time (s)**	**p-value**
Video Format								
PC	23.8	0.277	46.6	0.723	24.8	0.300	46.3	0.517
Phone/Tablet	25.2		44.2		26.0		43.5	
Gender								
Male	29.4	**0.002**	48.6	0.075	30.8	**<0.001**	48.6	**0.007**
Female	23.7		45.6		23.5		43.9	
Age Group								
18 – 29	23.8	**<0.001**	48.6	**0.003**	25.8	**0.001**	48.6	**<0.001**
30 – 39	16.4		41.3		17.2		33.5	
40 – 49	23.8		41.7		27.1		42.0	
50 – 59	25.2		47.5		27.1		48.6	
60 - >60	28.3		46.5		29.7		43.3	
Education								
Higher education (under-postgraduate), Diploma/Other professional qualification	22.2	**<0.001**	43.4	**<0.001**	23.5	**0.001**	43.3	**0.005**
School/Further education (GCSE/CSE/O Level, AS/A Levels or equivalent)	28.6		48.6		30.0		48.6	
Dog ownership								
No	26.5	**0.023**	48.6	**0.027**	29.8	**0.001**	48.6	0.141
Yes, currently/ prev.	23.6		43.8		23.6		43.7	
Length of ownership								
≤9 years	23.0	0.323	43.5	0.617	21.2	0.916	44.4	0.840
≥9 years	24.0		43.9		24.4		43.8	
Contact with dogs								
At least once a day	25.2	0.646	43.9	0.838	25.2	0.952	48.6	0.712
Several times a week	23.6		46.3		27.2		42.8	
Several times a month	24.1		46.6		25.0		47.1	
Less than once a month	23.8		46.8		23.3		46.5	
Bitten								
Yes	22.0	**0.001**	44.6	0.144	22.5	**0.009**	42.6	0.063
No	26.2		47.5		27.7		48.6	
Work with dogs								
No	25.8	**<0.001**	48.6	**<0.001**	28.1	**<0.001**	48.6	**<0.001**
Yes	16.3		41.3		16.7		33.3	
Hobby with dogs								
No	24.3	**0.003**	48.2	**<0.001**	27.0	**<0.001**	47.7	**0.015**
Yes	19.4		40.9		17.1		28.8	

Table 6.5 Pairwise comparison by age groups and distance travelled per video using a Mann-Whitney U test. Figures in bold indicated significant findings. All values are adjusted with Bonferroni correction.

Age group comparison	Aggressive (no sound) p-value	Non-reactive (no sound) p-value	Aggressive (sound) p-value	Non-reactive (sound) p-value
18-29 – 50-59	0.206	0.152	0.477	0.201
18-29 - ≥60	0.470	0.268	0.334	0.078
30-39 – 40-49	0.086	0.823	0.148	0.188
30-39 – 18-29	**0.036**	**0.007**	**0.010**	**<0.001**
30-39 – 50-59	**0.004**	0.768	**0.007**	0.186
30-39 - ≥60	**<0.001**	0.077	**0.004**	0.070
40-49 -18-29	0.305	**0.012**	0.550	0.054
40-49 – 50-59	0.450	0.168	0.252	0.252
40-49 - ≥60	0.081	0.111	0.172	0.528
50-59 - ≥60	0.511	0.813	0.810	0.650

6.3.3 Full video task

Participants were asked "*what emotion(s) do you think the dog is showing in the video*". The majority chose 'Anxious/Scared/Fearful' (97.0%; 513/529) followed by 'Anger' (31.6%, 167/529), 'Shy' (17.2%, 91/529) 'Sad/upset' (15.9%, 84/529); 'Calm and relaxed' (7.0%, 37/529); 'Excited' (6.2%, 33/529); 'Other' (e.g., "unsure", "uncertain", "wary", "frustration", "confused") (1.5%; 8/529) and 'I don't know' (1.0%, 5/529).

When prompted with options, most participants reported noticing the dog behaviours listed including lip licking (70.8%, 375/530), paw raise (78.9%, 418/530), head turn (90.8%, 481/530), backing away (98.1%, 520/530) and showing teeth (97.2%, 515/530). Given the high proportion of recognition (>90%) of the head turn, backing away and showing teeth, further statistical analysis regarding dog-related experience was only conducted for recognition of lip licking and paw raising. Both univariable (Appendix 6.6) and multivariable models (Table 6.6) indicate that participants who did not see the lip-licking behaviour were more likely to be individuals that did not own dogs and did not have a hobby or job with dogs. Participants who did not own a dog had not been previously bitten or did not have a job and/or hobby with dogs, were just as likely to not see the paw raise behaviour compared to individuals who had dog-related experience.

Table 6.6 Multivariable model of the likelihood of participants not seeing lip-licking behaviour. The multivariate model was supported by the Hosmer-Lemeshow statistic (p = 0.383).

Variable	**OR**	**95%CI**	**p-value**
Own(ed) dog(s)			
Yes	1		
No	2.707	1.717-4.268	**<0.001**
Previously bitten			
Yes	1		
No	1.262	0.823-1.935	0.286
Hobby with dogs			
Yes	1		
No	2.023	1.033-3.965	**0.040**
Job with dogs			
Yes	1		
No	3.209	1.756-5.864	**<0.001**

6.3.4 Presence

Median scores of the Igroup presence questionnaire (n = 531) varied between 2.5 and 4.0 (Table 6.7). There was evidence of a difference in the realism score between participants who completed the survey on a PC (mean = 2.4, n = 370) or tablet/mobile phone (mean = 2.6, n = 161) (Z = -2.68, p = 0.007). There was no evidence of differences between PC or mobile/tablets for the remaining three subscales.

A weak negative correlation between the aggressive video (no sound) and the 'realism experienced' presence rating (rho = -0.086, p = 0.048), but no further significant correlations between the remaining videos and presence ratings.

Table 6.7 Igroup presence questionnaire (IPQ) (range 0-6) mean and median scores for each of the four subscales.

	Mean	**SD**	**Median**	**IQR**
General presence	3.49	1.53	4.00	2
Spatial presence	2.85	0.78	2.80	1
Involvement	2.74	0.80	2.75	1
Realism experienced	2.48	0.70	2.50	1

6.4 Discussion

The current study found that participants were more willing to approach closer (approach-stop time) to the non-reactive dog than the aggressive dog. However, there was no difference found in approach-stop time between the aggressive video with and without sound.

This study is novel due to previous research into the reaction to and interpretation of dog behaviour generally relying on short video clips. In contrast, this current study used a continuous video of a single simulated dog displaying multiple behaviours, ranging from appeasement signals to a direct threat, and also assessed potential approach-stop times. The latter was found to differ by participant gender and dog-related experience, suggesting that men and those with less dog-related experience were willing to approach closer to a dog showing aggressive behaviours.

To date, research relating to approach distances mainly focuses on human psychology such as interpersonal distances (the distance between two people) (e.g. Perry *et al*., 2016). However, Wagels *et al*. (2017) did investigate the role of testosterone and its effect on men's interpersonal distance towards an aggressive, friendly, and neutral image of a man, woman and dog through a computer-based task. They found that all participants stopped further away from the angry human and dog compared to the image displaying natural or friendly emotions, which supports our findings. Interestingly, the group who were given the testosterone significantly reduced their distance, i.e. got closer, compared to the pre-treatment test indicating the effect of testosterone on personal distance in men towards an angry dog.

In the current study, male participants got closer to both the aggressive and nonreactive dogs compared to females. However, given the small number of males (n = 84) in comparison to females (n = 465), this result needs interpreting with caution. Having said this, it is consistent with previous research findings indicating that male adults and children are at an increased risk of being bitten compared to females in most (Shuler *et al*., 2008; Rosado *et al*., 2009; Westgarth *et al*., 2018; Tulloch *et al*., 2021), but not all studies (Park *et al*., 2019). Mathews and Lattal (1994) suggest that male children may be socially encouraged to take more risks and 'play rough' compared to females resulting in an increased risk of being bitten. However, this is not unique to dog bites as it has been highlighted that the risk of injury and injury rates in general higher in males than females (Udry, 1998).

Previous research indicates that dog vocalisations are often identified by individuals who correctly recognise aggressive dog behaviours (Pongrácz *et al*., 2005; Lakestani *et al*., 2014). The present study found no evidence of an effect of audio on approach-stop distances which could be due to participants, on average, stopping relatively early during the aggressive scenario at the point of appeasement signals, which have sounds such as whining during yawning and lip-licking. Only a small proportion of participants reached the later stages of aggression (levels 7 and 8), where the dog starts to bark and growl, involving significant noise and stereotypically associated with an aggressive dog. This suggests that the majority of participants utilised visual cues from the dog to identify a safe stopping distance, rather than overt vocalisations associated with aggression, e.g. growling, barking.

There was a positive correlation between approach-stop time and a measure of personality, indicating that those who rated higher in extroversion approached closer to the dog. Despite the various benefits that coincide with an extroverted personality, previous research has also found that increased rates of serious injuries are correlated with those who rated higher in extroversion (Nettle, 2005). This could be the increased likelihood of thrill-seeking or risk-taking or the reduced ability to recognise dangerous situations more readily. The only previous research to the author's knowledge that has investigated personality in relation to dog bites, Westgarth *et al*. (2018), found that individuals who had ever been bitten generally scored lower in the emotional stability personality trait, indicating higher levels of neuroticism. Davis *et al*. (2012) also found that less shy individuals were more likely to take risks when interacting with a therapy dog and reflected that children who are less shy and more outgoing or bold may react differently when approaching novel or unfamiliar settings.

Those with experience with dogs (owned, work(ed) or had a hobby with dogs) were more cautious as they stayed further away compared to those without dog-related experiences. These results may indicate that those with dog-related experience have increased knowledge about dog behaviour and/or experience regarding appeasement signals and defensive aggression. In contrast, previous research has shown that there is no difference in the ability to interpret dog behaviours between dog owners, non-dog owners, veterinarians or dog trainers (Tami and Gallagher, 2009). However, the latter study used videos of intraspecific behaviour compared to interspecific in this study.

The current study was not without limitations. This survey was a self-selected convenience sample, and therefore not representative of the UK population, which included a large proportion of females and dog owners. Female dog-owning respondents are often overrepresented in research focusing on human-dog interactions (e.g. Oxley *et al*., 2018; Herzog, 2021). This is especially important due to the finding that males moved closer to the dog than female participants. Future research should take this into account, for example a balanced proportion of male and females can be gathered or a more targeted approach.

It was positive to see individuals notice various dog behaviours. However, it is important to note that by the point participants had answered this question they had watched the aggressive dog video three times, including once in full. Therefore, this provided multiple opportunities to see the behaviours described. The approach stop task used a video attempting to simulate a user approaching an aggressive or relaxed dog. This setup only allowed for the approach and stop and did not allow an individual to move backwards, and to ensure an adequate amount of time per individual behaviour being displayed by the model dog. A slow approach speed was used, which limits how realistic a real situation it may be in terms of speed of approach to a dog in real life.

6.5 Conclusion

This study investigates UK public approach-stop distance in the presence of an aggressive and non-reactive dog model via an online survey. Participants move significantly closer to the non-reactive dog model compared to the aggressive dog model, supporting some recognition of aggressive behaviours and their effect on human behaviour. Participants who were male, had less experience with dogs (did not work or have a hobby with dogs, had not been previously bitten) and had a lower level school or college qualification were found to move closer to the aggressive dog. The extroversion personality trait was also positively correlated with approach stop time.

Future research needs to be conducted with more immersive technologies such as virtual and augmented reality and see if the findings using an online survey and videos and supportive in this more realistic context and measuring actual human behaviour.

APPENDICES FOR CHAPTER 6

Appendix 6.1 A breakdown of the levels and behaviours displayed in the aggressive survey video.

Time (seconds)	Distance (start to end of level) (m)	Level	Dog behaviours displayed
0.0 – 9.7 (9.7)	0.7m (5–4.3m)	0	• Lying down, panting, looking left and right. 
9.7 – 28.0 (18.3)	1.4m (4.3-2.9 m)	1	• Stands up, put paw forward, lip lick, steps back, slowly wagging tail, steps forward, yawns and lip licks, paw raise 
28.0 – 33.6 (5.6)	0.4m (2.9-2.5)	5	• Head turns with paw raise, head turn with whites of the eye showing (whale eye). Tail now under body. 
33.6 – 45.3 (11.7)	0.9 (2.5 – 1.6)	6	• Slowly moves backwards whilst growling and direct eye contact, ears move back and then stands still.

			
45.3 – 52.3 (7.0)	0.5 (1.6 – 1.1)	7	• Crouches slightly, barks, direct eye contact, ears back, growling, mouth slightly open with teeth showing. 
52.3 – 56.6 (4.3)	0.3 (1.1 – 0.8)	8	• Fully crouching, growling, clench teeth showing, eyes widened with whites of the eye visible, lip lick, growling. 

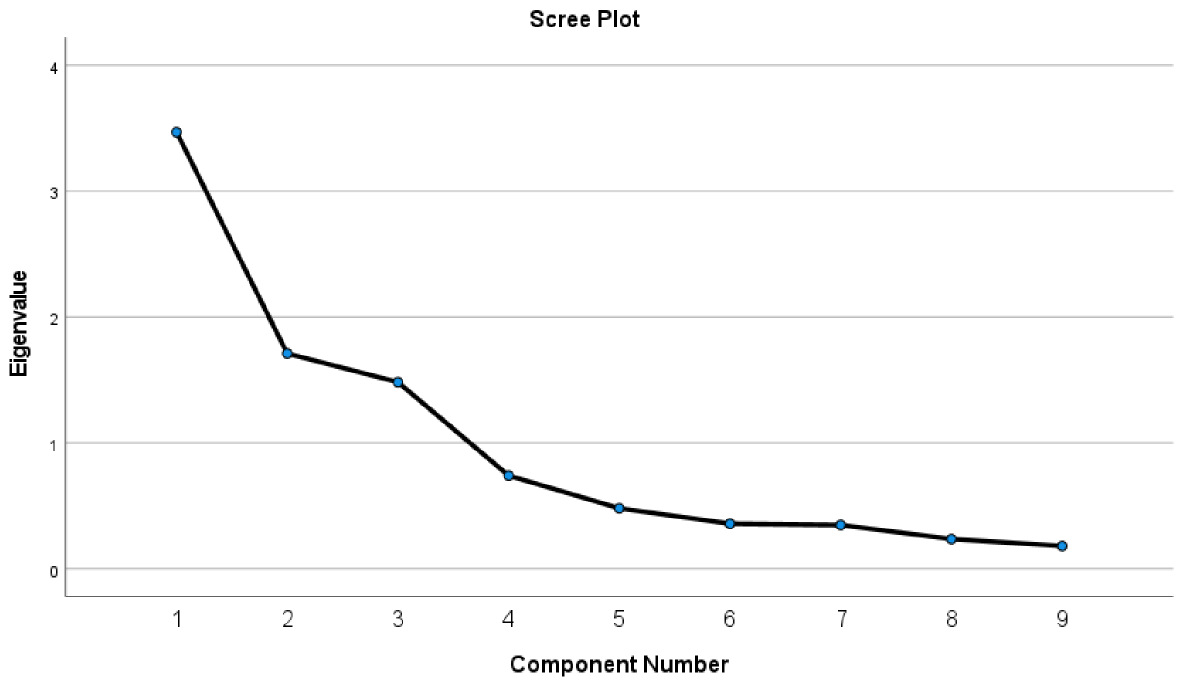
Appendix 6.2 Demographics, dog ownership, experience and personality of 559 UK participants.

Variable	n	%
Gender		
Female	465	84.7
Male	84	15.3
Missing	10	
Age group		
18 – 29	184	33.0
30 – 39	103	18.5
40 – 49	111	19.9
50 – 59	84	15.1
60 – 60+	76	13.6
Missing	1	
Highest education level		
Higher education (under/postgraduate), Diploma, other professional qualification (e.g., nursing/teaching)	393	72.4
School, further education (GCSE/CSE/O Level, AS/A Levels or equivalent)	150	27.6
Missing	16	
Dog ownership		
No, never owned a dog	128	22.9
Yes, not currently but have previously	113	20.2
Yes, I currently own dogs	318	56.9
If yes, how long have you owned dogs		
Less than 5 years	84	19.8
Between 5 and less than 9 years	57	10.2
9 years or longer	284	66.8
Missing	3	
Average frequency of contact with dogs		
Less than once a month/never	118	21.1
Several times a month	125	22.4
Several times a week	179	32.0
At least once a day	137	24.5
Work with dogs (paid or voluntary)		
No	418	74.8
Yes	141	25.2
Hobby with dogs		
No	448	80.1
Yes	111	19.9
Personality traits	**Mean**	**Median**
Agreeableness	4.99	5.0
Conscientiousness	5.15	5.0
Emotional stability	4.44	4.5
Openness	4.94	5.0
Extrovert	4.08	4.0

Appendix 6.3 Univariate logistic regression of whether a person was bitten and demographic and dog experience-related factors.

	N	Previously bitten (n)	Previously not bitten (n)	OR	CI 95%	p-value
Gender						
Female	465	223	242	1		
Male	84	42	42	1.085	0.682 – 1.727	0.73
Age group						
18 – 39	287	113	174	1		
40 - >60	271	157	114	2.121	1.512 – 2.973	**<0.001**
Highest education level						
School and further education (GCSE/CSE/O Level, As/A Levels or equivalent)	150	61	89	1		
Higher education (under-postgraduate), Diploma / Other professional qualification	393	203	190	**1.559**	**1.065-2.82**	**0.022**
Dog ownership						
Have never owned a dog	124	25	99	1		
Own(ed) dogs (< 9 years)	141	63	78	**3.198**	**1.845-5.545**	**<0.001**
Own(ed) dogs (≥9 years)	284	178	106	**6.650**	**4.032–10.967**	**<0.001**
Frequency of contact with dogs						
Several times a month/ once a month/ never	243	97	146	1		
At least once a day/ several times a week	316	174	142	**1.844**	**1.314 - 2.589**	**<0.001**
Hobby with dog						
No	448	193	255	1		
Yes	111	78	33	**3.123**	**1.995 – 4.888**	**<0.001**
Job with dogs						
No	418	171	247	1		
Yes	141	100	41	**3.523**	**2.332-5.322**	**<0.001**
Personality traits		**Mean**	**Median**			
Agreeableness	559	4.99	5	0.943	0.804 - 1.106	0.471
Conscientiousness	559	5.15	5	0.960	0.833 - 1.107	0.574
Extroversion	559	4.08	4	0.977	0.868 - 1.100	0.701
Openness	559	4.94	5	1.121	0.951 - 1.322	0.175
Emotional stability	559	4.44	4.5	1.027	0.908 - 1.162	0.670

Appendix 6.4 Scree plot for principal component analysis



Appendix 6.5 Analysis of approach stop time and personality traits using spearman rank correlation. The figures in bold indicate significant correlations.

Video		**Agreeableness**	**Extrovert**	**Conscientiousness**	**Openness**	**Emotional Stability**
Aggression with sound	rho	-.071	**.122**	0.018	0.031	0.067
	Sig.	.095	**0.004**	0.665	0.471	0.113
	N	559	**559**	559	559	559
Aggression with no sound	Rho	-.045	**.132**	0.014	0.026	0.055
	Sig.	.289	**0.002**	0.734	0.544	0.198
	N	559	**559**	559	559	559
Non-reactive with no sound	rho	-.033	**.090**	0.030	0.068	0.030
	Sig.	.439	**0.034**	0.481	0.110	0.475
	N	559	**559**	559	559	559
Non-reactive with sound	rho	-.035	0.081	0.009	0.083	0.015
	Sig.	.405	0.054	0.824	0.051	0.716
	N	559	559	559	559	559

Appendix 6.6 Univariable logistic regression of participants who did not see lip lick or paw raise behaviour and dog experience (n = 530).

	Sample	Lip Lick				
Dog ownership	**n (%)**	**Yes**	**No**	**OR**	**95%CI**	**p-value**
Curr./prev. own dogs	405 (76.4)	314 (77.5)	91 (22.5)	1		**<0.001**
Do not own dogs	125 (23.6)	61 (48.8)	64 (51.2)	3.62	2.376-5.517	
Previously bitten						
Yes	253 (47.7)	199 (78.7)	54 (21.3)	1		**<0.001**
No	277 (52.3)	176 (63.5)	101 (36.5)	2.115	1.435-3.116	
Hobby with dogs						
Yes	103 (19.4)	91 (88.3)	12 (11.7)	1		**<0.001**
No	427 (80.6)	284 (66.5)	143 (33.5)	3.818	2.024-7.203	
Job with dogs						
Yes	133 (25.1)	118 (88.7)	15 (11.3)	1		**<0.001**
No	397 (74.9)	257 (64.7)	140 (35.3)	4.285	2.411-7.618	

CHAPTER 7. AN INTERNATIONAL ONLINE SURVEY EXPLORING THE ROLE OF DEMOGRAPHICS, DOG RELATED EXPERIENCE AND DOG COAT COLOUR, SIZE AND ENVIRONMENT ON USER APPROACH-STOP DISTANCE USING A VIRTUAL DOG MODEL

7.1 Introduction

Human perceptions of dogs have been studied often focusing on factors including coat colour and size which are often associated with breed type. As previously highlighted in the systematic literature review (see Chapter 2; Oxley *et al*., 2022), dog phobia studies involving VR dog models frequently choose specific breeds such as Rottweilers or Dobermans, indicating a bias in selection by breed, size and/or coat colour. Such breeds are often negatively portrayed in popular media, often used as guard dogs, and as a result may be more likely to be considered dangerous (Podberscek, 1994; Harding, 2012, p. 27; Kikuchi and Oxley, 2017). Additionally. As previously stated (Chapter 5) past research has explored the role of dog coat colour and human perceptions of dogs and their behaviour i.e. black dog syndrome.

Several in-person studies have been conducted exploring the response of unfamiliar people toward dogs in public. Wells (2004) used an experimenter who walked a dog down an urban street followed by an assessor monitoring the approaching unfamiliar people's reactions e.g. form of acknowledgement (ignore, smile, etc.). The study involved six different scenarios including with one of three dogs (puppy, adult yellow Labrador and adult Rottweiler). More people did not acknowledge the experimenter when they were walking a Rottweiler compared to both Labradors. Similarly, Blecker *et al*. (2013) studied the effect of dog size (small/large) and coat colour (dark/pale) on the effect of a stranger when walking down an inner-city street. They found that members of the public more frequently altered their path by stepping aside when in the presence of a dog with a dark coat (Border Collie cross) compared to dogs with a pale coat (Golden Retriever) of the same size. Again, limitations for interpretation include the dogs varying in multiple ways other than just the factor being examined.

More recently, Briones and Marshall (2022) conducted an online virtual two-dimensional 'stop-distance' task investigating interpersonal distance between a virtual individual (avatar) and multiple dog breeds categorised as high-rated aggression (e.g. Doberman, Rottweiler, German Shepherd) or low rated aggression (Golden Retriever, Beagle, Collie) based on prior research (Briones *et al*., 2022), standing at the side of a virtual handler. The authors found that interpersonal distance was influenced by the perception of the aggressiveness of a breed i.e. they stayed further away from breeds that were perceived to be more aggressive compared to those that were not. However, the latter study only presents a condition where both the human and dog are together, and again breeds vary in size and coat colour too. More research is needed in multiple contexts to compare interpersonal distance with and without the owner/handler present. Furthermore, the latter study was limited by the static 2D images (avatars) with no associated human or dog behaviour being displayed. The role of dog behaviour is likely to be influential in whether a person approaches a dog and a dog's reaction. Finally, it appeared that all dogs were on a lead and therefore could be perceived as being sufficiently under control. Therefore, other contexts need to be explored such as in an owner's home where a dog may not be on a lead.

To further understand how people behave around aggressive dogs in different contexts and based on different appearances of dogs further research is required. In research to date, either just images or a well-behaved dog are used to assess how people behave when walking past dogs. Of course, this assessment would not be possible in the presence of a dog displaying undesirable behaviours due to the possibility of injury or compromised welfare of the dog. The use of a virtual dog model is preferable to help understand human behaviour and perceived safest proximity in response to a dog displaying behaviour in response to a perceived threat. Further, the role of dog size, breed and coat colour can be altered whilst the dog displays identical behaviours. Therefore, the aim of the current study was to:

i) Assess and compare participants' perceived safest proximity to approaching a virtual aggressive dog in three different experimental comparisons, including:
   - Small, medium or large dog
   - Yellow or black coat colour
   - Indoor or outdoor environment.
ii) Assess respondent demographics including country, age, sex, education; and dog-related experience, including dog ownership, dog related job, previously bitten, safety training; on the perceived safest proximity to the dog, including across the five different virtual scenarios.
iii) Assess and compare the coat colour, size of the dog and environment on the participant's ability to recognise, and their interpretation of, aggressive behaviours.
iv) Assess the perceived blame for the dog's behaviour.

7.2 Method

7.2.1 Participants

7.2.1.1 Recruitment

An anonymous international online survey recruiting adults (18 years and older) was conducted from the 15th September 2021 to the 9th October 2021. Recruitment of participants was conducted through convenience sampling which involved posting a recruitment poster, description and link to the survey on social media platforms including Facebook, Facebook groups (including general non-dog related and dog specific groups), Twitter and LinkedIn. The advertisement on social media called for both dog owners and non-dog owners from all countries to complete an anonymous survey about their perceptions of dog behaviour. The survey was hosted in the software Gorilla Experiment Builder (www.gorilla.sc) (Anwyl-Irvine *et al.,* 2020).

7.2.1.2 Sample size and demographics

A total of 1,606 responses were received. After data cleaning this was reduced to 1,590 participants. Unless otherwise stated 1,590 respondents answered the questions. The majority were female (88.2%), aged between 18 – 49 (61.6%) (Appendix 7.1). Participants currently lived in the UK/Ireland/Isle of Man (39.2%), North America (36.5%), Australasia (11.5%), Europe other (excluding UK/Ireland/Isle of Man) (8.5%) and Other (e.g. Africa, South America, Asia) (4.3%) (Appendix 7.1). There was no significant difference between gender ($\chi^2 = 5.048$, $p = 0.282$), age ($\chi^2 = 22.086$, $p = 0.140$) or region ($\chi^2 = 8.841$; $p = 0.920$) across the five videos. The majority of participants (78.3%) currently owned a dog(s), 12.9% did not currently but had previously owned a dog(s) and 8.8% stated to have never owned a dog (Appendix 7.2). Furthermore, most participants (94.7%) agreed that they would not feel nervous if they saw most dogs and agreed that they could recognise when a dog is showing aggressive (95.4%), scared or fearful (93.9%) or relaxed behaviours (96.8%) (Appendix 7.3).

7.2.2 Ethics

The study, including the survey, was approved by the University of Liverpool's Veterinary Research Ethics Committee (Reference: VREC1111) and conducted in compliance with the Declaration of Helsinki. An information sheet was provided at the start of the survey which including information about the purpose of the study, ethical approval information, anonymity (i.e. no personal identifying information would be collected), voluntary participation and contact information. All participants were required to consent to take part before they could proceed.

7.2.3 Online survey

7.2.3.1 Pilot study

Prior to the distribution of the survey a pilot study of eight participants, including both male and female, varying age groups and dog ownership status, was conducted. The feedback was reviewed which suggested minor amendments and the survey updated. All participants could play the videos. Once the survey was updated the final survey was distributed.

7.2.3.2 Online survey

At the start of the survey participants were presented with an information sheet which covered the purpose of the research, eligibility (18 or over and be able to read and write in English), withdrawal criteria, participant anonymity, data usage, funding and researcher contact information. This was followed by a compulsory question to confirm that respondents had read the information sheet and agreed to take part, were aware that the survey and details/data provided were anonymous and that the respondent was 18 years old or older. Participants were also asked if their sound was on and what country they currently lived in. The remainder of the survey consisted of four sections. (see surveys here: https://tinyurl.com/JOxleyPhDDigital).

7.2.3.3 Survey section one - dog ownership and dog related experience

Section one included dog ownership status (currently and/or previously or never owned a dog). If answered 'yes' to dog ownership, participants were asked about the number of dogs and length of ownership, including dogs that were currently and/or previously owned, size of the dogs owned and reason for dog ownership. In addition, the experience individuals had with dogs, including the average frequency of contact with dogs and if they currently or had previously had a dog related job. Participants were also asked if they had a phobia or were scared or fearful of most dogs. If they answered 'yes' to the latter question they were sent to the end of the survey.

Respondents were asked to rate their agreement, via a five point Likert scale, with ten statements based on the premise "When walking alone (without any owned dogs) in public", five statements related to the perceived feelings in the presence of dogs (e.g. "*I feel relaxed in the presence of most dogs*"), two relating to the anticipation of dogs (e.g. "*I scan for dogs when I go to unfamiliar places"* and three about individual ability to interpret scared/fearful, aggressive, relaxed behaviours (e.g. "*I can recognise when a dog is showing scared/fearful behaviours*"). Three questions from the dog phobia questionnaire (Vorstenbosch *et al*., 2012) were incorporated into the ten statements.

7.2.3.4 Survey section two – approach-stop task

Participants were randomly allocated to watch one of five videos. These included videos focusing on size, including small, medium and large (yellow coat, indoor environment), coat colour black or yellow (medium size, indoor environment) and environment including an indoor or outdoor area (medium size, yellow) (Figure 7.1-7.4 and Chapter 3). Before the video, a screen was displayed explaining the purposed of the task by stating "*We would like to see how close you would get to the dog based on how comfortable you feel*" and were asked to press stop "*at the point they felt they would stop, if they would stop approaching the dog*".

Figure 7.1 Comparison of different dog sizes (small, medium, and large).

Figure 7.2 Survey view of the large dog, yellow coat in the indoor scenario (level 1 (left); level 8 (right)).

Figure 7.3 Survey view of the medium dog, yellow coat in the outdoor scenario (level 1 (left); level 8 (right)).

Figure 7.4 Survey view of the medium size dog, black coat in the indoor scenario (level 1 (left); level 8 (right)).

The virtual environment and dog model was developed by the Virtual Engineering Centre (Daresbury, UK) to a real-world scale (see Chapter 3). All videos started at five metres from the centre (middle) of the dog model regardless of size of the dog.

Once the video started, a three second countdown was displayed. The video then displayed the slow continuous approach (0.075m/s) towards the dog model. The total time of the video and time in each level varied based on the size of the dog (Table 7.1 and 7.2). Participants could press stop at any point and the survey would proceed to the next screen. If the stop button was not pressed the entire video would run and once complete the next page of the survey would be shown automatically. For a list of behaviours displayed at different levels (see Chapter 3). Level 2, 3 and 4 were not displayed as this was dependent on the participant being static (i.e. in virtual reality) and is not applicable in this setting.

Table 7.1 An overview of the five videos, dog model, video length, speed of approach and closest distance the video gets to the dog.

Video	Video length (s)	Video distance (start to end) (m)	Speed of approach (m/s)	Closest distance to the dog (nose) (m)
Video A (Large, Yellow, Indoor)	53	4.0	0.075	0.6
Video B (Small, Yellow, Indoor)	63	4.7	0.075	0.6
Video C (Medium, Yellow, Indoor)	56	4.2	0.075	0.6
Video D (Medium, Yellow, Outdoor)	56	4.2	0.075	0.6
Video E (Medium, Black, Indoor)	56	4.2	0.075	0.6

Table 7.2 The position of the user and the dog models nose in the virtual environment and the distance between the user and the dog at each level (0 – 8). Note: at the start position of the user video was 5m from the centre of the dog (0m) regardless of size.

	Small (Indoor, yellow)			**Medium (Indoor & yellow / Indoor & black / Outdoor & yellow)**			**Large (Indoor, yellow)**		
Level	**User pos. (m)**	**Dog nose pos. (m)**	**Dist. Between user-dog (m)**	**User pos. (m)**	**Dog nose pos. (m)**	**Dist. Between user-dog (m)**	**User pos. (m)**	**Dog nose pos. (m)**	**Dist. Between user-dog (m)**
Start	5	0.3	4.7	5	0.4	4.6	5	0.5	4.5
1	4.2	0.3	3.9	4.3	0.4	3.9	4.4	0.5	3.9
5	2.7	0.5	2.2	2.9	0.7	2.2	2.9	0.9	2
6	2.3	0.5	1.8	2.5	0.7	1.8	2.7	0.9	1.8
7	1.1	-0.3	1.4	1.6	0.2	1.4	1.8	0.4	1.4
8	0.6	-0.3	0.9	1.1	0.2	0.9	1.3	0.4	0.9
End	0.3	-0.3	0.6	0.8	0.2	0.6	1	0.4	0.6

7.2.3.5 Survey section three - full video, dog behaviour, blame and realism

Participants were asked to watch the same video they had been previously allocated but on this occasion they were asked to watch the entire video from start to finish without pressing a button. Upon completion of the video, participants were asked if they saw the dog perform specific behaviours including lip lick, paw raise, head turn, showing its teeth, backing away and yawning. For each behaviour it was asked what they thought the behaviour was communicating from a single choice closed ended answer (e.g. not a threat, dominant, in pain, wanting to play, a threat, thirsty/too warm, tired, I don’t know, other). The latter answer options were based on the previous results, see Chapter 4. In addition, for each behaviour, it was asked what emotion the behaviour represented (e.g. anger, anxious, calm/relaxed, excited, frustrated, happy/friendly, sad, upset, scared/fearful, shy, I don’t know, other).

A multiple-choice question asked “*In general, why do you think the dog is behaving this way*”. Answers included ‘the dog is happy to see me’, ‘the dogs owners are not present’, ‘the dog is scared/fearful of me approaching it’, ‘the dog wants to play’, ‘the dog has had a bad past experience’, ‘the dog is in pain or unwell’, ‘the dog is not well trained/socialised’, ‘the dog is relaxed’, ‘the dog is trying to protect its bowl/bed/area’, ‘I don’t know’, ‘other’. Once again, these options were based on previous results (Chapter 4). Participants were also asked who they thought was to blame for the dog’s behaviour. Multiple choice options included ‘the dog’, ‘the owner/caregiver’, ‘yourself (the person approaching the dog)’, ‘no-one’ and ‘I don’t know’.

Similar to Chapter 5, five questions were asked about the perceived realism of the dog's appearance/behaviour/vocalisations, the environment and user virtual movement compared to a real dog, environment, and human movement.

7.2.3.6 Survey section four - demographics, dog bite and safety training

The final section asked about participant information including, age, sex and education level. It was also asked if they had ever taken part in dog safety/bite prevention education or training. Participants were asked if they had ever been bitten by a dog. Answers were based on Oxley *et al*.'s (2019, p. 43) definition of a bite as "causing at least a bruise or skin puncture" or not bitten 'No, not previously bitten' / 'No, bitten but did NOT cause bruising or puncture to the skin'.

7.2.4 Data analysis

Sample demographics were described using descriptive statistics. For each of the five approach-stop videos, normality testing was conducted using the Kolmogorov-Smirnov Test and was subsequently followed by a log transformation (Log10). However, data remained non-normally distributed and therefore nonparametric tests were used.

Although participants were randomly allocated to one of five videos, a chi-square was conducted to ensure there was no evidence of differences in age, gender and region across all five videos. For each analysis, both individual videos are presented ('small', 'medium', 'large', 'outdoor', and 'black coat') and a separate 'combined' category where all videos were combined and analysed together as a single group.

To compare participants perceived safest proximity to approaching a virtual aggressive dog across the different virtual scenarios, a Kruskal Wallis test, followed by a post hoc pairwise test using Dunn's test, was used to compare the five approach-stop video conditions.

To explore the effects of owner demographics, dog ownership and experience (including having been bitten) on perceived safest proximity to the dog Kruskal Wallis tests were used, followed by a Mann Whitney U test for pairwise analysis.

To assess respondent demographics on the perceived safest proximity to the dog, across the five different virtual scenarios and all combined, multivariable linear regression analysis was conducted. All variables were forced into the multivariable model. Categorical variables with more than two options (i.e. age group and region) were dummy coded for each option (0, 1). Assumptions for multicollinearity, outliers, normality of residuals and homoscedasticity were met (Pallant, 2020). A p-value of <0.05 was considered statistically significant.

Analysis of participant interpretation of aggressive behaviours and allocation of blame for the dog's behaviour in each scenario was explored using descriptive statistics due to the minimal variation in responses. A p-value <0.05 was considered statistically significant.

Data analysis was conducted in IBM SPSS statistics (IBM SPSS Statistics for Windows, Version 27.0, Armonk, NY: IBM Corp). Boxplots were produced using Origin (Pro) (2020b) (OriginLab Corporation, Northampton, MA, USA).

7.3 Results

7.3.1 Contact with dogs

The average frequency of contact with dogs, not including those dogs that an individual owned, was at least once a day (31.5%), several times a week (34.8%), several times a month (21.9%), less than once a month (11.0%) or never (0.8%). Forty percent (40.2%) had previously or currently worked in a job, either paid or voluntarily, that involved direct contact with dogs.

7.3.2 Approach-stop video task

Across all five video groups there was evidence of a difference in approach-stop times ($\chi^2(4) = 47.271$, $p<0.001$). Dunn's post hoc pairwise tests with Bonferroni correction found that participants moved significantly closer to the 'small' dog (Md = 29.3s, IQR = 17.4 -41.2) compared to the 'large' (Md = 25.6s, IQR = 14.4 - 35.7, z = -4.600, $p<0.001$) and 'medium' (Md = 22.1s, IQR = 15.2 – 22.1, z = 3.704, p = 0.002) dogs (Figure 7.5). There was no evidence of a difference in approach-stop time between the 'indoor' and 'outdoor' videos (z = 1.634, p = 0.102) and between the 'yellow' and 'black' dog (z = 2.646, p = 0.081).

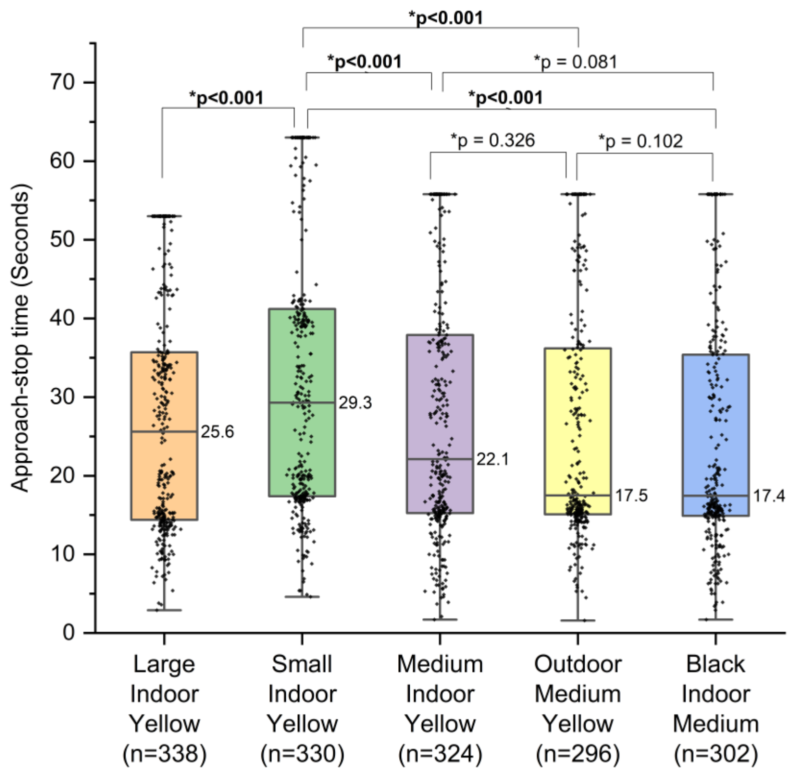


Figure 7.5 Box and whisker plot of the approach-stop time(s) in each of the five videos. The coloured boxes and the horizontal lines indicate the 25th, 50th (median time) and 75th percentile. Whisker displays above and below the boxes indicates the highest and lowest data points within 1.5x interquartile range.

Over half of all participants went no further than Level 1 aggression in all videos (large 53.9%, small 51.5%, medium 59.0%, outdoor 65.5%, black 66.9%) (Figure 7.6).

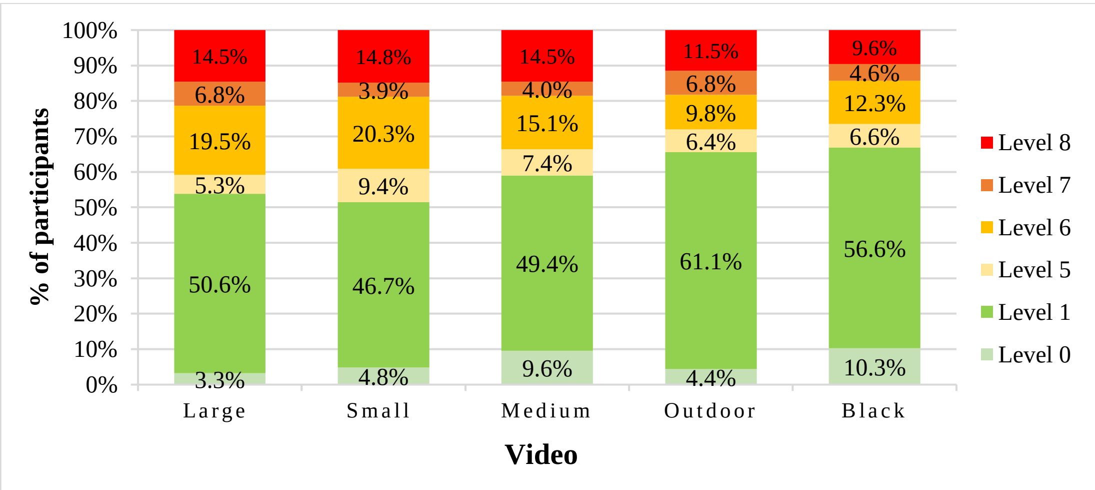


Figure 7.6 The proportion of participants who reached each level of aggression (0,1, 5, 6, 7, 8). Levels 2, 3, 4 were not included as this was only applicable if the scenario involved a participant to be static.

7.3.3 Approach-stop time and gender, age and region

Males moved significantly closer than females in the ‘large’ (males Md = 35.5s, females Md = 21.4s, U = 3644, p = 0.006), ‘medium’ (males Md = 31.0s, females Md = 20.6s, U = 4291, p = 0.035), ‘outdoor’ (males Md = 32.8s, females Md = 17.0s, U = 2590, p = 0.004) and ‘black’ (males Md = 27.6s, females Md = 16.6s, U = 2320.5, p = 0.008) videos. There was no difference in distance travelled by between males and females in the ‘small’ video (males Md = 34.7s, females Md = 28.9s, U = 5003, p = 0.115). When all videos were combined, males (Md = 32.6s) moved significantly closer to the dog than females (Md = 20.1s) (U = 87995, p<0.001).

There was evidence of a difference in approach-stop time between age groups for four out of the five videos (‘large’ ($\chi^2(4)$ = 10.250, p = 0.036), ‘small’ ($\chi^2(4)$ = 16.668; p = 0.002), ‘outdoor’ ($\chi^2(4)$ = 31.232; p<0.001) and ‘black ($\chi^2(4)$ = 20.302; p<0.001)). Of the four videos, participants aged 30-39 and 40-49 consistently reported the lowest median approach-stop time (i.e. furthest away from the dog) and those aged 50-59 and 60+ report the highest median times (closest to the dog) (Appendix 7.4). Dunn’s tests with Bonferroni correction revealed a significant difference in approach-stop time between age groups for each video including participants aged 30-39 and 50-59 (black (z = 15.576, p<0.001); outdoor (z = 13.684, p<0.001)), 30-39 and 60 and over (small (z = 16.938, p = 0.038); black (z = 15.872; p<0.001); outdoor (z = 14.905, p<0.001)) and 40- 49 and 60 and over (small (z = 17.524, p = 0.002)). There was no difference between all age groups in the large video.

Regarding the participants region, there was only a difference in approach stop times between region in the outdoor scenario ($\chi^2(4)$ = 16.901, p = 0.002) and the combined (all videos) group ($\chi^2(4)$ = 21.039, p<0.001). However, the ‘other’ region consistently had the highest median approach-stop times (i.e. moved closest to the dog) across all five videos (Appendix 7.4). Dunn test with Bonferroni correction revealed that in there was a significant difference in approach-stop time between regions in the ‘outdoor’ and combined (all videos) videos including between ‘Australasia’ and ‘UK/Ireland/Isle of man’ (outdoor (z = 2.861, p = 0.042)), ‘Australasia’ and ‘other’ (outdoor (z = 31.792, p = 0.012); combined (all videos) (z = 65.198, p<0.001)) and ‘other Europe’ and ‘other’ (outdoor (z = 34.334, p = 0.038); combined (all videos) (z = 68.266; p<0.001)), ‘UK/Ireland/Isle of man’ and ‘Other’ (combined (all videos) (z = 58.625; p = 0.005)).

7.3.4. Approach-stop time and dog ownership and job with dogs

Participants who had never owned a dog had a higher median approach stop time (i.e. closer to the dog), (Md = 32.9s) across the combined dataset than those who own(ed) dogs (Md = 20.2s)

(U = 76561, p<0.001). This was also evident in the ‘large’ (never owned (Md = 33.3s), currently/previously owned (Md = 20.6s) (U = 3329, p = 0.011) and ‘medium’ (never owned (Md = 39.5s), currently/previously owned (Md = 21.0s) (U = 2343.5, p<0.001) videos.

Similarly those who did not currently own dog moved significantly closer, compared to those who currently owned dogs, in the ‘large’ (currently own Md = 20.3s, do not own Md = 32.6s) (U = 12085.5, p<0.001), ‘medium’ (currently own Md = 21.3s, do not currently own Md = 32.3s) (U = 9520, p = 0.035), ‘small’ (currently own Md = 25.6s, do not currently own Md = 33.1s) (U = 9.520, p = 0.009), ‘outdoor’ (currently own Md = 17.0s, do not currently own Md = 22.2s) (U = 8451.5, p = 0.020) videos and ‘all videos’ combined (currently own Md = 20.0s, do not currently own Md = 30.4s) (U = 257011.5, p<0.001). There was no evidence of a difference between current dog ownership status in the ‘black coat’ video (currently own Md = 16.4s, do not currently own Md = 20.9s) (U = 9822.5, p = 0.066).

Of those participants who previously or currently owned a dog, there was no difference in approach stop-times based on dog related experience (e.g. length of ownership, number of dogs, size of dogs) (Appendix 7.4). However, individuals who had not currently or previously had a job with dogs moved significantly closer to the dogs in all five videos and in ‘all videos’ compared to those who currently or previously had a job with dogs (Appendix 7.4).

7.3.5 Approach stop times and past experience of being bitten

There was a significant difference between approach-stop times between participants across all videos (combined) that had been bitten and those that had not (U = 269502.5, p = 0.001). Participants who had not been bitten moved significantly closer (Md = 24.6s, n = 723) than those who had been bitten (Md = 20.0s, n = 823). This was also observed in two of the videos; ‘small’ (not bitten Md = 32.0s, bitten Md = 27.5s, U = 10886; p = 0.029) and ‘outdoor’ (not bitten Md = 21.4s, bitten Md = 16.5s, U = 8224; p = 0.005).

The majority of respondents (76.8%, 629/819) said that the dog bite incident(s) had not changed their likelihood of them approaching unfamiliar dogs, whereas 22.0% (180/819) stated they were less/much less likely to approach an unfamiliar dog and 1.2% (10/819) participants stated they are more likely to approach an unfamiliar dog.

7.3.6 Approach stop time and safety training

Over a quarter of participants (26.4%, 404/1546) had previously taken part in some form of dog safety and/or dog bite prevention education/training. Participants who had not previously taken part in safety training moved significantly closer to the dog compared to those who had previously taken part in safety training across all five videos (‘large’ (U = 12579.5, p = 0.002), ‘medium’ (U = 10609.5, p = 0.002), ‘small’ (U = 12108.5, p = 0.025), ‘outdoor’ (U = 9948, p = 0.020) and ‘black’ (U = 10972; p<0.001) and ‘all videos (combined)’ (U = 279677.5, p<0.001) (Appendix 7.4).

7.3.7 Multiple regression model

The models were all significant with a R^2 value ranging from 9.3% (all videos (combined)) to 17.9% (‘outdoor’). Some consistent findings occurred: 1) gender (male) was positively associated compared to females in the ‘large’ (B = 5.234, 95%CI = 0.264 – 10.203), ‘outdoor’ (B = 7.272, 95%CI = 2.040 – 12.505), and the ‘All videos (combined)’ (B = 4.883, 95%CI = 2.475 – 7.292) models; 2) ‘region (other)’ was positively associated compared to UK in ‘large’ (B = 12.926, 95%CI = 4.870 – 20.982), ‘outdoor’ (B = 10.174, 95%CI = 1.693 – 18.656), ‘black coat’ (B = 9.771; 95%CI = 1.693 – 18.565) and ‘all videos (combined)’ (B = 9.072, 95%CI = 5.172 – 12.972) . All results can be seen in Table 7.3.

7.3.8 Behaviours and emotion of the dog models

The most common behaviour reportedly seen was ‘showing of the teeth’ across all five videos. The majority (≥80%) saw all behaviours including lip licking (range: 80.6% - 95.3%), yawning (range: 86.5% - 95.0%), raised paw (range: 79.5% - 94.4%), head turn (range: 88.4% - 93.1%), back away (range: 99.1% - 99.7%) and showing teeth (range: 98.0% - 99.7%). Furthermore, almost all participants heard the vocalisations in all videos (99% - 100%).

Regarding behavioural interpretation, participants interpreted lip lick, yawn, paw raise, head turn and moving backwards as a combination of ‘A threat’, ‘Not a threat’, ‘I don’t know’ and ‘Other’ (Figure 7.7). In contrast, over 70% of respondents stated that showing teeth indicated that the dog was ‘A threat’.

Table 7.3 Multiple linear regression models and categorical variables associated with higher approach-stop time for five different video and all video combined.

	Video 1 - Large				Video 2 - Small				Video 3 - Medium			
Variable	**b**	**b (s.e.)**	**95% CI**	**P**	**b**	**b (s.e.)**	**95% CI**	**P**	**b**	**b (s.e.)**	**OR (95% CI)**	**P**
Constant	31.983	2.459	(27.144, 36.823)	**<0.001**	35.72	3.683	(28.467, 42.963)	**<0.001**	36.027	3.451	(29.234, 42.820)	**<0.001**
Video - Large												
Video - Small												
Video - Medium												
Video - Outdoor												
Video - Black												
Gender (Female)	1											
Gender (Male)	5.234	2.525	(0.264, 10.203)	**0.039**	3.548	2.997	(-2.351, 9.447)	0.238	3.728	2.809	(-1.801, 9.257)	0.186
Age (18 - 29)	1											
Age (30 - 39)	-3.748	2.485	(-8.638, -1.142)	0.133	-0.871	2.950	(-6.676, 4.934)	0.768	-0.267	2.764	(-5.708, 5.174)	0.923
Age (40 - 49)	-4.342	2.597	(-9.452, 0.768)	0.096	-4.009	3.082	(-10.075, 2.057)	0.194	0.431	2.889	(-5.255, 6.116)	0.882
Age (50 - 59)	0.983	2.569	(-4.073, 6.039)	0.702	1.905	3.050	(-4.096, 7.907)	0.533	1.345	2.858	(-4.280, 6.971)	0.638
Age (≥60)	1.892	2.682	(-.3.385, 7.170)	0.481	6.896	3.183	(0.631, 13.160)	**0.031**	3.591	2.983	(-2.280, 9.463)	0.230
Region (UK/IRL/IOM)	1											
Region (North America)	-0.146	1.903	(-3.890, 3.599)	0.939	2.976	2.259	(-1.469, 7.421)	0.189	3.421	2.117	(-0.745, 7.587)	0.107
Region (Australasia)	3.501	2.718	(-1.848, 8.849)	0.199	3.144	3.226	(-3.205, 9.493)	0.331	1.235	3.023	(-4.715, 7.186)	0.683
Region (Other Europe)	3.166	3.064	(-2.863, 9.194)	0.302	-2.840	3.636	(-9.996, 4.316)	0.435	1.172	3.408	(-5.535, 7.879)	0.731
Region (Other)	12.926	4.094	(4.870, 20.982)	**0.002**	4.373	4.859	(-5.189, 13.935)	0.369	8.47	4.554	(-0.492, 17.433)	0.064
Ever owned a dog (No)	1											
Ever owned a dog (Yes)	-1.875	3.568	(-8.896, 5.146)	0.600	1.459	4.235	(-6.876-9.764)	0.731	-10.623	3.969	(-18.435, -2.811)	**0.008**
Currently own a dog (Yes)	1											
Currently own a dog (No)	-3.728	2.429	(-8.508, 5.146)	0.126	-5.104	2.883	(-10.777, 0.570)	0.078	-0.374	2.702	(-5.692, 4.944)	0.890
Jobs with dogs (No)	1											
Jobs with dogs (Yes)	-0.901	1.845	(-4.532, 2.729)	0.626	-1.942	2.190	(-6.252, 2.367)	0.376	-2.304	2.052	(-6.343, 1.735)	0.262
Bitten (No)	1											
Bitten (Yes)	-0.636	1.698	(-3.977, -2.704)	0.981	-3.430	2.015	(-7.395, 0.535)	**0.09**	0.638	1.888	(-3.078, 4.355)	0.736
Safety Training (No)	1											
Safety Training (Yes)	-3.863	2.035	(-7.968, 0.142)	0.059	-3.265	2.416	(-8.019-1.489)	0.178	-4.02	2.264	(-8.475, 4.360)	0.077
Model	**R2**	**F**		**p**	**R2**	**F**		**p**	**R2**	**F**		**p**
	0.119	(14, 303) 3.918		p<0.001	0.108	(14, 296) 2.571		0.002	0.094	(14, 289) 2.153		0.010

Variable	**Video 4 - Outdoor**				**Video 5 – Black coat**				**All videos (combined)**			
	b	**b (s.e.)**	**OR (95% CI)**	**P**	**b**	**b (s.e.)**	**OR (95% CI)**	**P**	**b**	**b (s.e.)**	**OR (95% CI)**	**P**
Constant	29.885	3.265	(23.457,36.314)	**<0.001**	27.452	3.296	(23.457, 36.314)	**<0.001**	32.341	1.524	(29.055, 35.628)	**<0.001**
Video - Large									1			
Video - Small									4.517	1.198	(2.167, 6.867)	**<0.001**
Video - Medium									0.243	1.203	(-2.117, 2.603)	0.840
Video - Outdoor									-1.206	1.235	(-3.628, 1.216)	0.329
Video - Black									-2.978	1.224	(-5.379, -0.576)	**0.015**
Gender (Female)	1				1				1			
Gender (Male)	7.272	2.658	(2.040, 12.505)	**0.007**	5.133	2.682	(2.04, 12.505)	0.057	4.883	1.228	(2.475, 7.292)	**<0.001**
Age (18 - 29)	1				1				1			
Age (30 - 39)	-5.433	2.615	(-10.582, -0.284)	**0.039**	-2.96	2.64	(-10.582, -0.284)	0.263	-2.664	1.208	(-5.034, -0.294)	**0.028**
Age (40 - 49)	-1.133	2.733	(-6.513, 4.248)	0.679	0.692	2.758	(-6.513, 4248)	0.802	-1.727	1.262	(-4.203, 0.749)	0.171
Age (50 - 59)	3.83	2.704	(-1.493, 9.153)	0.158	5.173	2.729	(-1.493,9.153)	0.059	2.565	1.250	(0.113, 5.016)	**0.040**
Age (≥60)	5.246	2.822	(-0.311, 10.802)	0.064	4.019	2.848	(-0.311, 10.802)	0.159	4.250	1.302	(1.695, 6.804)	**0.001**
Region (UK/Ireland/IOM)	1				1				1			
Region (North America)	-0.509	2.002	(-4.451, 3.434)	0.8	0.011	2.021	(-4.451,3.434)	0.996	1.181	0.924	(-0.632, 2.994)	0.202
Region (Australasia)	-7.69	2.86	(-13.322, -2.058)	**0.008**	2.279	2.887	(-13.322, -2.058)	0.430	0.530	1.319	(-2.058, 3.117)	0.688
Region (Other Europe)	-2.46	3.224	(-8.807, 3.887)	0.446	-0.897	3.254	(-8.807, 3.887)	0.783	-0.256	1.488	(-3.174, 2.662)	0.864
Region (Other)	10.174	4.308	(1.693, 18.656)	**0.019**	9.771	4.348	(1.693, 18.565)	**0.025**	9.072	1.988	(5.172, 12.972)	**<0.001**
Ever owned a dog (No)	1				1				1			
Ever owned a dog (Yes)	1.169	3.755	(-6.224, 8.561)	0.756	-2.369	3.79	(-6.224, 8.561)	0.532	-2.459	1.732	(-5.857, 0.939)	0.156
Currently own a dog (Yes)	1				1				1			
Currently own a dog (No)	-2.961	2.556	(-7.994, 2.072)	0.248	-0.047	2.58	(-7.994, 2.072)	0.986	-2.481	1.181	(-4.797, -0.164)	**0.036**
Jobs with dogs (No)	1				1				1			
Jobs with dogs (Yes)	-0.92	1.942	(-4.742, -2.903)	0.636	-5.122	1.96	(-4.742, 2.903)	**0.009**	-2.207	0.896	(-3.964, -0.450)	**0.014**
Bitten (No)	1				1				1			
Bitten (Yes)	-3.927	1.786	(-7.444, -2.072)	**0.029**	-0.048	1.803	(-7.444, -0.410)	0.979	-1.458	0.824	(-3.075, 0.159)	0.077
Safety Training (No)	1				1				1			
Safety Training (Yes)	-1.911	2.142	(-6.128, 2.306)	0.373	-4.066	2.162	(-6.128, 2.306)	0.061	-3.408	0.990	(-5.363, -1.467)	**<0.001**
Model	**R2**	**F**		**p**	**R2**	**F**		**p**	**R2**	**F**		**p**
	0.179	(14, 269) 4.195		p<0.001	0.139	(14, 272)		p<0.001	0.093	(14, 1485) 10.835		<0.001

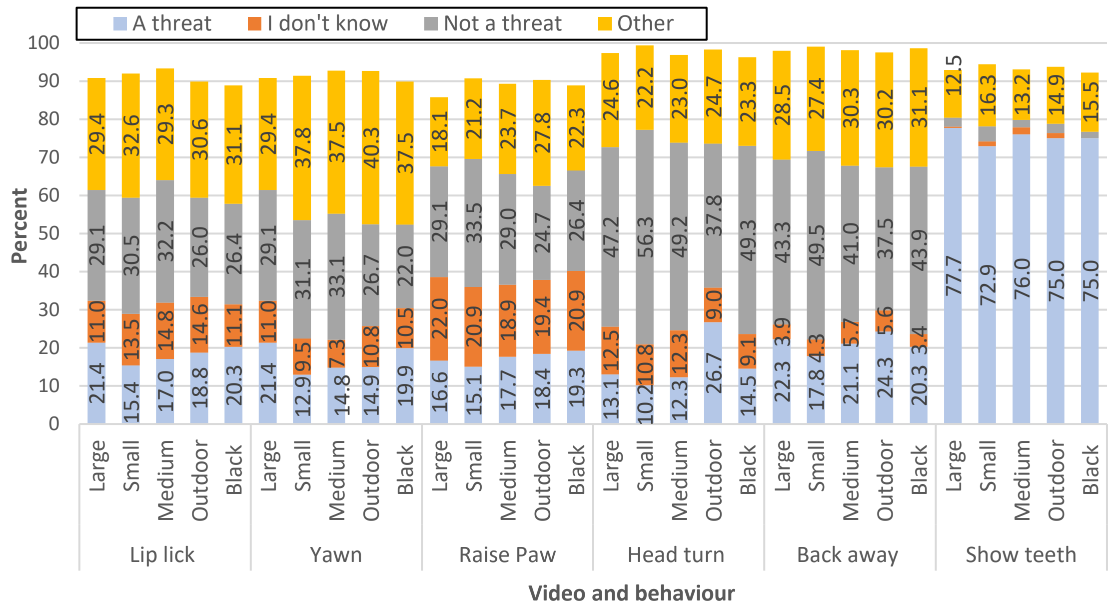


Figure 7.7 The highest four categories chosen for each of the five videos about participants perceptions about what dog behaviours (lip lick, yawn, paw raise, head turn, back away and show teeth) were communicating about the dog.

7.3.9 Emotion

The majority (≥70%) stated that all behaviours were either anxious or scared/fearful (Figure 7.8). Anger was chosen more frequently in the 'show teeth' behaviour compared to all other behaviours. See Appendix 7.5 for all participants responses regarding emotions and behaviours.

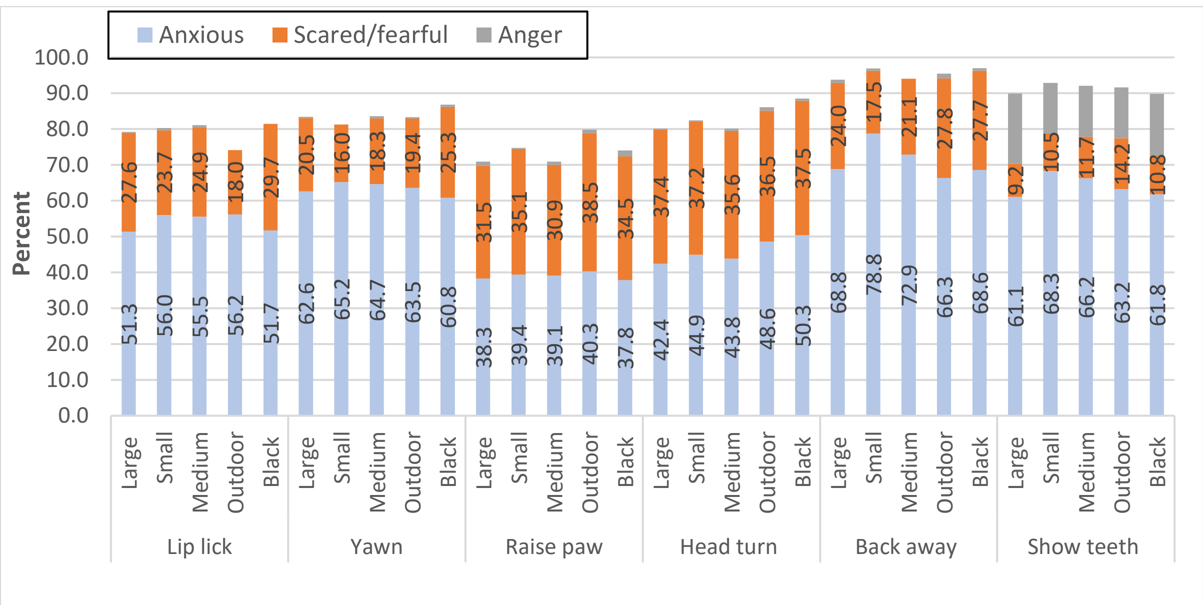


Figure 7.8 The two most frequent emotions for the six behaviours included 'anxious' and 'fearful' or 'scared'. Anger only increased in the 'show teeth' behaviour.

The vast majority (>95%) for all five videos stated the dog is scared or fearful (Table 7.4).

Table 7.4 Response to the multiple-choice question "*In general why do you think the dog is behaving in the way?*".

	Large (n = 337)		**Small (n = 325)**		**Medium (n = 317)**		**Outdoor (n = 288)**		**Black (n = 296)**	
	n	%	n	%	n	%	n	%	n	%
The dog is scared/ fearful of me approaching it	324	96.1	313	96.3	303	95.6	277	96.2	287	97.0
The dog has had a bad past experience	112	33.2	111	34.2	113	35.6	76	26.4	100	33.8
The dog is trying to protect it's bowl/ bed/area	94	27.9	90	27.7	90	28.4	43	14.9	77	26.0
The dog is not well trained/socialised	64	19.0	75	23.1	72	22.7	47	16.3	66	22.3
The dog is in pain or unwell	61	18.1	57	17.5	72	22.7	39	13.5	53	17.9
The dog's owners are not present	57	16.9	59	18.2	65	20.5	44	15.3	50	16.9
I don't know	3	0.9	7	2.2	6	1.9	3	1.0	4	1.4
Other	19	5.6	12	3.7	16	5.0	19	6.6	24	8.1

7.3.10 Blame

The majority (88-90%) of participants blamed themselves for the reason the dog was behaving in the way it was. Over one-quarter of participants blamed the owner/caregiver. There was a low occurrence of respondent blaming the dog, however, of those that did, the highest proportion of respondents blamed the large (4.9%) and black (3.7%) dog (Table 7.5).

Table 7.5 Respondents blame for the dog's behaviour (aggressive scenario). Multiple choice question.

	Large		**Small**		**Medium**		**Outdoor**		**Black**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Yourself (the person approaching the dog)	300	89.0	286	86.9	278	88.0	259	89.9	261	88.8
The owner/caregiver	100	29.7	95	28.9	104	32.9	78	27.1	82	27.9
No one	16	4.8	20	6.1	14	4.4	17	5.9	26	8.8
The dog	10	3.0	9	2.7	7	2.2	5	1.7	11	3.7
I don't know	13	3.9	27	8.2	18	5.7	16	5.6	12	4.1
Total	337		329		317		288		294	
Missing	1		1		7		8		8	

7.3.11 Realism

Regardless of dog size or colour of the dog model, over 80% (82.5%-84.4%) and 88% (88.3%-93.2%) agreed with the statement that the dog's appearance and behaviour was 'like that of a real dog' respectively (Appendix 7.6). Regarding the realism of the dog's vocalisations, between 93.3% and 96.2% of respondents agreed with the statement "*The dog's vocalisations were like that of a real dog"*. There was variation in agreement regarding realism of the environment ranging from 49.2% (small) to 70.6% (outdoor) (Appendix 7.6).

7.4 Discussion

This study explored approach-stop distances between five videos of virtual dog models displaying identical aggressive behaviours with different sizes (small, medium and large), environments (indoor and outdoor) and coat colours (yellow and black). Participants moved significantly closer to the small dog compared to the medium and large dog. Participants also moved closer to the yellow dog compared to black. In general, there was consistent evidence that males moved closer than females although smaller numbers of males participated in the study. These findings may explain behaviours around dogs related to bite risk.

7.4.1 Size

Differences by size could be due to several reasons, for example, participants who watched the small dog video were the lowest in rating of all behaviours (lip lick, yawn, paw raise, head turn, showing teeth) as 'a threat' (Figure 7.7) compared to all other dog models. This is possibly due to the perception that they were less likely to cause injury compared to larger dogs. This is somewhat concerning given that previous research has reported that in comparison to large dogs, small size dogs have been found to be more likely to bite adults (Guy *et al*., 2001) and children (Messam *et al*., 2018). However, it is important to note that dog bite incidents are often multifactorial in nature (e.g. context etc).

Participants could have perceived the small dog as a Labrador puppy or juvenile. This would be similar to other research. For example, Gazzano *et al*. (2013) stated that members of the public were significantly more likely to want to interact with a handler standing with a puppy (Labrador (Yellow), Golden Retriever and Border collie) or large dog (Golden Retriever and crossbreeds) compared to a medium (Black Labrador, Golden Retriever and Pointer) or small dog (Jack Russell, 2 crossbreeds). Blecker *et al*. (2013) found that small pale dogs were perceived by the general public to be more friendly simply due to their size compared to a large dog with a light-coloured coat and a small dog with a dark coat. However, in all the latter studies dogs were with a handler and not alone or in a confined area as seen in the present study. Further research would be useful to incorporate a owner/person within the video to see if/how individuals perception of the dog changes. Research could explore the perceived 'cute effect' (also known as 'Kindchenschema') in virtual dog models (i.e. paedomorphic characteristics), as previously identified from photographs of puppies (Borgi *et al*., 2014; Paul *et al.*, 2023) and rabbits (Harvey *et al*., 2019), and the perception of different smaller dog breeds and appearance. These features have not only been selected for in companion animals through domestication, but they also promote caregiving, attention and elicit positive emotions in humans in turn help to facilitate social relationships (see review by Kringelbach *et al*., 2020). In the present study, out of the five virtual dog model, the small dog received the lowest rating in terms of 'a threat' over all behaviours (see appendix 7.5).

The current study did not specifically explore the perceptions of the dog's age. Previous research has indicated that the age of dogs has a role in individual perceptions of dogs. In the present study, there were limited signs of ageing (e.g. older dog are noted to have grey hair around the face and muzzle, reduce activity levels and a higher percentage body fat than young dogs due to slower metabolism (Bellows *et al*., 2015)). Future work could explore this using the virtual dog model and development to further to explore if age of a dog and its physical attributes (e.g. body condition score) have an effect on participants perceptions and effect on approach-stop distance.

7.4.2 Coat colour

Participants moved significantly closer to the yellow dog compared to the black dog. Further, the highest proportion of participants stopped approaching the black dog at level 0 and 1 and were the lowest proportion to reach level 8.

It has been suggested that the interpretation of facial expression and behaviour signal are difficult more difficult to identify in dog with black coats (Trevathan-Minnis *et al*., 2021). Therefore, participants could have been acting more cautious. Another explanation could be that the contrast between white teeth and a black coat could have emphasised specific signals. The present study only used two colours (yellow and black) for the dog model. Further research should investigate the role of varying gradients of black and dark (e.g., liver, chocolate) coat colours. The current model has 256 colours that can be chosen from. In addition, coat type (e.g. short, long), which has been briefly explored using modified photographs (Wells and Hepper, 1992) and had a role in the likelihood of being adopted with longer coat being preferred compared short coats (Siettou *et al*., 2014), is another area which may be useful to explore especially with a virtual dog model as this does not require multiple live dogs.

7.4.3 Blame

This study provides evidence that participants often blame themselves when presented with an aggressive unfamiliar dog, in an unfamiliar environment, or they may blame the owner, but rarely the dog. More specifically, this study also demonstrates that virtual environments produce similar findings that are seen in real life scenarios. Our findings are consistent with previous dog bite related research (Westgarth and Watkins, 2015; Oxley *et al*., 2018).

7.4.4 Realism

It was positive to note that most respondents agreed that the dog model's behaviour, appearance, and vocalisation as similar to that of a real dog. However, the agreement with the statement regarding the realism of the environment varied. The highest agreement was regarding the outdoor scenario. This could be due to the complexity of the environment. Also, the indoor environment scenario resembled a living room at night compared to the outdoor environment during the day. The overall colour of the scenario was different, i.e., indoor walls appeared to be brown, and outdoor area had park bench with grass and trees in the background. There were also different background sounds. The outdoor environment had birds singing, whereas the living room had people talking resembling an urban area. The latter factors should all be taken into account in future studies and both environments should be similar with regarding to the time of day, weather etc.

7.4.5 Limitations

This study used an online survey mainly promulgated through social media. Therefore, this was a convenience sample and thus these results are prone to sampling bias. For example, although the response for this international survey was large, most respondents were from the UK and the USA. Future studies could better target specific regions such as Asia, Africa and the middle east especially due to the risk associated with zoonotic disease transmission in these regions i.e. rabies (see Chapter 1).

Males appeared to approach closer to the dog than females. This is consistent with previous dog bite research indicating that male are more frequently admitted to hospital than females (Westgarth 2018; Tulloch *et al*., 2021). However, caution is needed when interpreting these results due to the small number of males (11.8%, 177/1504). The majority of respondents were female, a result often found in human-animal interaction surveys (Herzog, 2021), although this clearly also applies to studies involving virtual animals.

Regarding the approach stop videos, participants distance from the dog at the start was measured by the centre of the dog (i.e. all participant started at 5 metres from the centre of the dog). However, length of the video in total was based upon a stop point that ended at a close point to the dog's nose. Given that the two of the five dogs were different sizes, participants thus started off slightly further away from the dog model's nose in the small dog than the larger dog. This also impacted the duration of the videos across the different sizes of dog models resulting in different length of videos. Therefore, given the slight variation in distance it could be argued that some of the signals displayed by the dog were more difficult to see. However, this was not apparent in the feedback regarding the meaning and emotion of the behaviours displayed. In future, all models could have been at the same distance based on the nose rather than the midpoint of the dogs and displayed the same behaviour at the same time points for more accurate comparisons.

7.5 Conclusion

This study found evidence for differences in participant willingness to approach a dog based on size (small, medium, large) and colour (yellow, black) but not environment (indoor, outdoor). Participants moved closer to the small dog and stayed furthest away from the outdoor and black dogs. Those who were male, non-dog owners and from 'other' regions appeared to be those who got closer to the dog models. Participants often blame themselves or the dog owner for the dogs' behaviour. Given this is the first time this model has been used for online research with an international sample, the perception of the dog model realism was reassuringly high.

APPENDICES FOR CHAPTER 7.

Appendix 7.1 Respondent demographics (Region, age, gender and highest education level) (n = 1590).

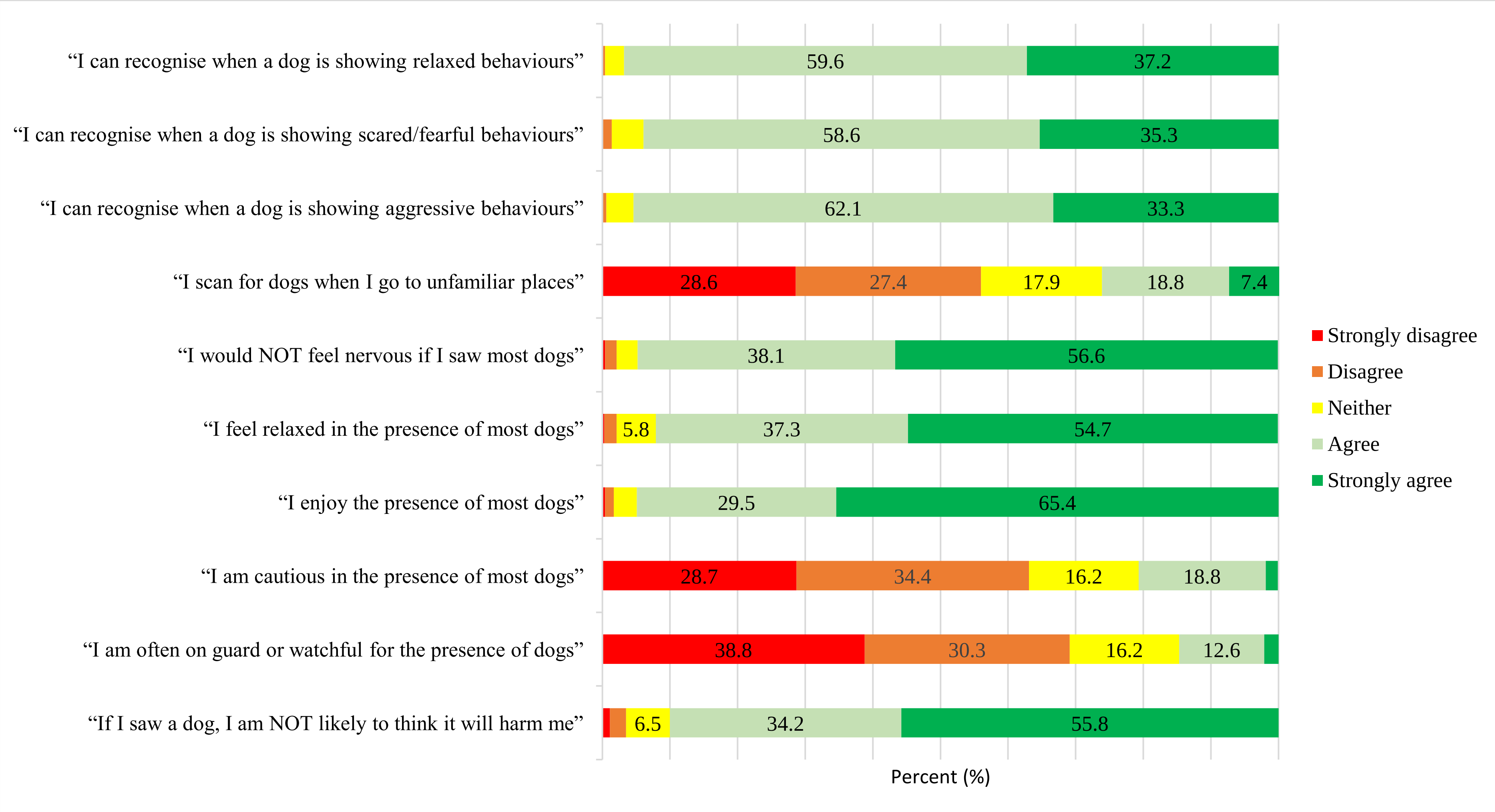
Variable	n	%
Region		
UK/ Ireland/ Isle of Man	624	39.2
North America	580	36.5
Australasia	183	11.5
Other Europe	135	8.5
Other*	68	4.3
Total	1590	100.0
Age		
18-29	304	19.8
30-39	346	22.5
40-49	296	19.3
50-59	321	20.9
60+	270	17.6
Total	1537	100.0
Missing	53	
Sex		
Male	177	11.8
Female	1327	88.2
Total	1504	100.0
Missing	86	
Highest Education Level		
University postgraduate/ graduate degree (MSc; Mres; MS; PhD)	506	33.3
Undergraduate education (College and/or University (e.g., BSc; BSc (Hons); BS; BA)	674	44.3
Secondary/high school	303	19.9
Did not complete secondary/high school	10	0.7
Total	1521	100.0
Missing	28	

*Included countries within Africa, Asia, Middle East, Russia or South America.

Appendix 7.2 Current and/or previous dog ownership experience.

	n	%
Current/previous dog ownership		
Yes - I currently and have previously owned a dog(s)	1055	66.4
Yes - I currently own a dog(s) but not previously owned dogs	189	11.9
Yes - I currently do not own a dog(s) but I have previously owned a dog(s)	205	12.9
No - I have never owned a dog	141	8.9
Total	1590	100.0
If yes, how many dogs owned (currently/previously) (n = 1447)		
1	222	15.3
2	257	17.8
3	234	16.2
4	171	11.8
5 or more	563	38.9
Total	1447	100.0
Missing	2	
If yes, how long have you owned dogs for (currently/previously) (n = 1445)		
Less than 1 year	34	2.4
Between 1 year but less than 3 years	72	5.0
Between 3 years but less than 5 years	82	5.7
Between 5 years but less than 7 years	66	4.6
Between 7 years but less than 9 years	74	5.1
Between 9 years but less than 13 years	160	11.1
13 years or more	957	66.2
Total	1445	100.0
Missing	4	
Size of dog(s) owned (currently/previously) [multiple choice] (n = 1448)		
Toy (e.g., Chihuahua / Pomeranian)	161	11.1
Small (e.g., Terrier)	567	39.2
Medium (e.g., Collie / Spaniel)	881	60.8
Large (e.g., Labrador / German Shepherd)	856	59.1
Giant (e.g., Great Dane / Irish Wolfhound)	105	7.3
Total	1448	100.0
Missing	1	
Reason for dog ownership (currently/previously) [multiple choice] (n = 1448)		
Pets / companionship	1429	98.7
Working dog (e.g., sheep / police / hunting / sled dogs)	99	6.8
Security / guard dog (against people and / or animals)	76	5.2
Assistance dog (e.g., Guide dog)	52	3.6
Breeding	44	3.0
Other (dog sports agility, dog showing, therapy dog, puppy walking)	105	7.3
Total	1448	100.0
Missing	1	

Appendix 7.3 Ten dog related statements in response to "When walking alone (without any owned dogs) in public…" (n = 1590). (Note: figures <5% are not shown).



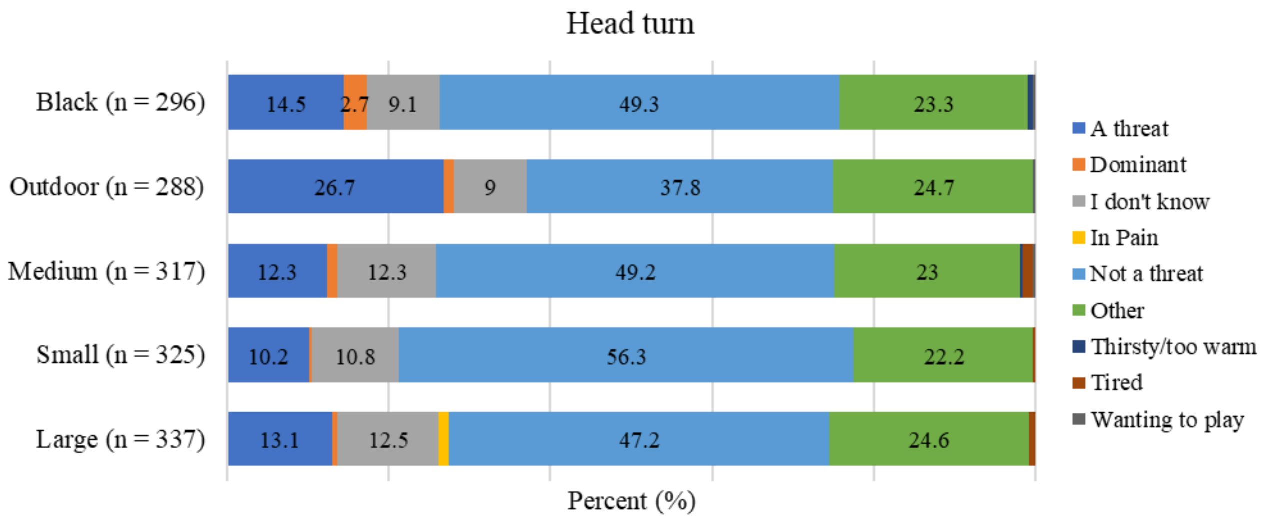
Appendix 7.4 Approach-stop time broken down by demographics, dog ownership and dog related experience. Mann Whitney U test for categories with two options and Kruskal-Wallis for options with >2 options.

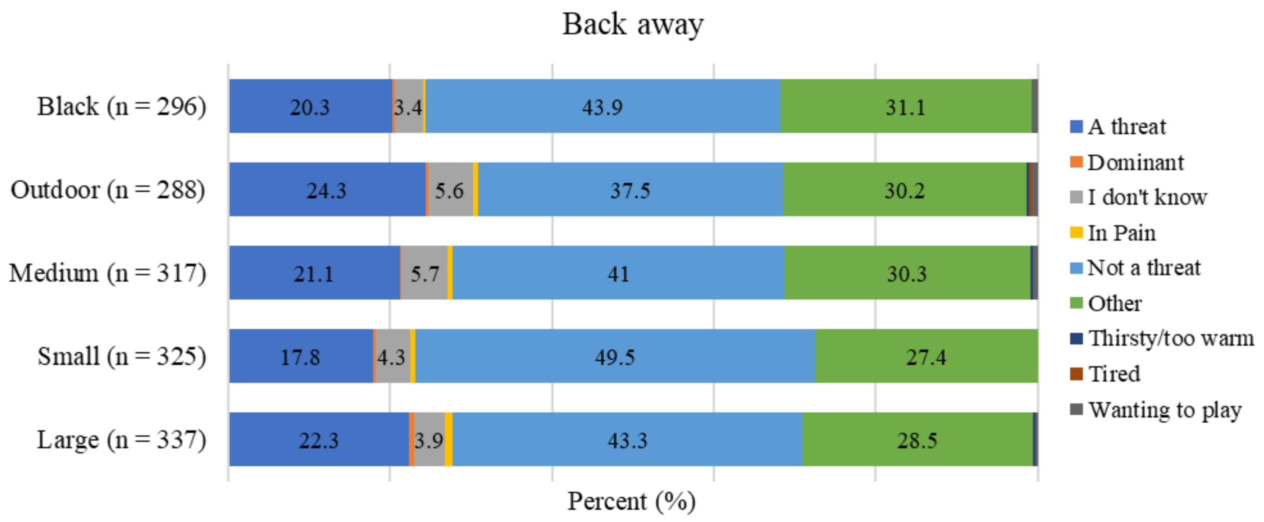
	Large (n = 338)		**Small (n = 330)**		**Medium (n = 324)**		**Outdoor (n = 296)**		**Black (n = 302)**		**All Videos (n = 1590)**	
	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P
Demographics												
Gender												
Male	35.5	**0.006**	34.7	0.115	30.1	**0.035**	32.8	**0.004**	27.6	**0.008**	32.6	**<0.001**
Female	21.4		28.9		20.6		17.0		16.6		20.1	
Education												
University postgraduate /graduate degree (MSc; Mres; MS; PhD)	21.4		30.2		23.1		17.3		17.5		20.7	
Undergraduate education (College and/or University (e.g. BSc; BSc (Hons); BS; BA)	24.5	0.304	26.9	0.528	26.6	0.307	17.7	0.727	16.3	0.256	20.4	0.346
Secondary/high school	29.1		28.8		20.1		16.9		20.0		21.4	
Age group												
18-29	29.5		29.3		26.3		17.2		17.2		22.35	
30-39	17.6		22.3		18.0		15.2		15.3		16.55	
40-49	19.9	**0.036**	20.0	**0.002**	20.6	0.403	16.3	**<0.001**	16.0	**<0.001**	18.45	**<0.001**
50-59	30.1		33.7		21.4		21.8		22.1		27.90	
60+	39.5		39.4		27.9		29.7		24.1		29.30	
Region												
UK / Ireland / Isle of Man	23.0		26.4		21.3		19.3		19.6		20.90	
North America	19.9		31.7		22.8		19.1		16.6		21.00	
Australasia	28.7	0.154	28.9	0.268	22.3	0.317	15.8	**0.002**	15.7	0.173	20.20	**<0.001**
Other Europe	32.6		19.8		16.4		15.6		15.7		17.40	
Other	43.8		33.7		30.5		33.2		29.1		33.20	
Dog ownership												
Ever owned a dog												
Yes	20.6	**0.011**	28.9	0.99	21.0	**<0.001**	17.4	0.159	16.9	0.066		**<0.001**
No	33.3		33.1		39.5		19.7		27.3			

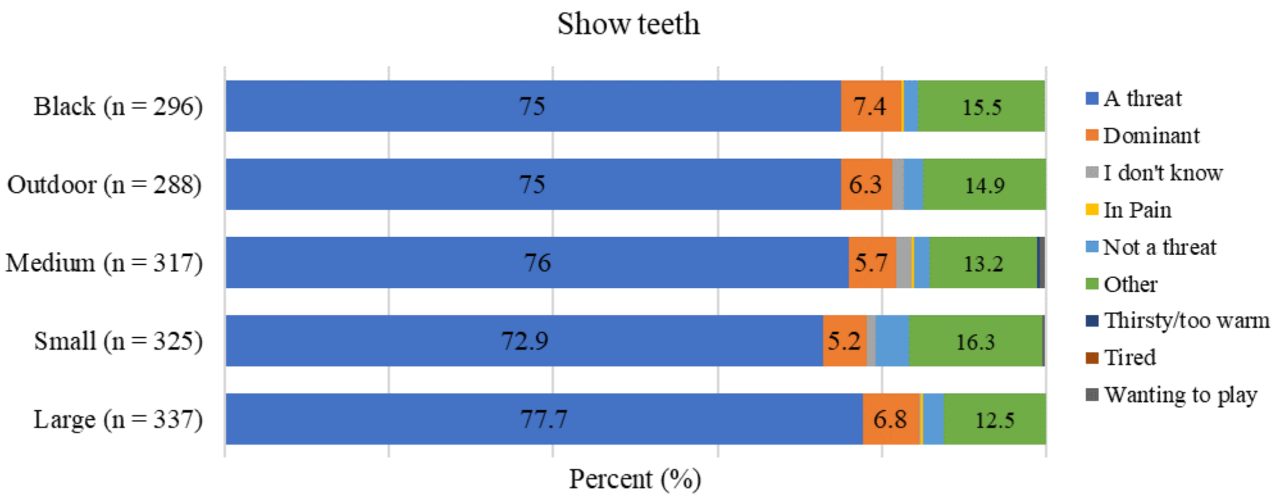
	Large (n = 338)		Small (n = 330)		Medium (n = 324)		Outdoor (n = 296)		Black (n = 302)		All Videos (n = 1590)	
	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P
Currently own a dog												
Yes	20.3	**<0.001**	25.6	**0.009**	21.3	**0.035**	17.0	**0.020**	16.4	0.061	20.00	**<0.001**
No	32.6		33.1		32.3		22.2		20.9		30.40	
Dog owners - Length of ownership												
0 - <5 years	22.6	0.731	25.6	0.530	18.8	0.546	15.5	0.142	17.0	0.851	18.9	0.256
5 - <9 years	20.6		24.2		19.9		15.5		19.2		19.8	
9 or longer years	21.0		29.9		21.8		17.8		16.9		20.5	
Dog owners - No. of dog												
1	20.5	0.529	29.9	0.549	18.8	0.174	16.0	0.137	17.5	0.667	20.5	0.179
2	22.5		33.3		28.0		20.3		16.6		21.3	
3	28.0		20.1		16.7		15.5		18.8		19.4	
4	17.8		30.2		20		16.7		16.9		18.3	
5 or more	27.2		29.1		22.3		20.0		16.4		21.4	
Dog owners - Size of dogs												
Toy/Small	26.6	0.701	19.7	0.114	27.1	0.120	21.6	0.097	17.3	0.951	21.3	0.390
Medium	19.9		28.9		19.7		16.5		17.3		19.5	
Large /Giant	20.2		29.4		22.3		15.6		16.1		20	
Contact with dogs												
Freq. of contact with dogs												
At least once a day	19.5	0.418	31.7	0.177	19.9	0.359	19.6	0.612	16.9	0.499	20.1	0.227
Several times a week	28.7		25.4		22.0		16.8		16.8		20.7	
Several times a month	26.2		26.8		23.4		19.1		17.3		22.3	
Less than once a month / never	19.1		36.0		31.5		18.0		18.5		27.0	
Job with dogs												
Yes	18.8	**0.013**	21.2	**0.011**	19.7	**0.014**	16.2	**0.008**	15.8	**<0.001**	17.7	**<0.001**
No	29.6		32.5		27.7		20.2		20.8		27.5	
Dog bites and safety training												
Bitten by a dog												

	Large (n = 338)		Small (n = 330)		Medium (n = 324)		Outdoor (n = 296)		Black (n = 302)		All Videos (n = 1590)	
	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P	Median Time (s)	P
Not previously or yes, but did not cause a bruise/puncture	28.4	0.198	32.0	**0.029**	21.8	0.773	21.4	**0.005**	18.3	0.378	24.6	**0.001**
Yes, a bite causing either a bruise, or single or multiple puncture wounds to the skin	20.3		27.5		22.2		16.5		16.8		20.0	
If bitten, by familiar / unfamiliar dog												
Unfamiliar	24.2	0.348	20.8	0.698	21.8	0.738	16.3	0.539	16.5	0.850	20.1	0.740
Familiar	20.0		26.8		21.4		16.6		17.1		19.8	
Both Familiar/Unfamiliar	16.8		29.7		27.5		16.3		17.1		20.0	
If bitten, how many times												
Single	19.9	0.563	27.3	0.793	22.3	0.735	16.6	0.580	17.5	0.407	19.8	0.949
Multiple	23.8		25.8		20.6		16.5		16.1		20.2	
If bitten, Size of dog(s)												
Toy/Small	26.6	0.821	19.7	0.109	27.1	0.304	21.6	0.209	17.3	0.369	21.3	0.699
Medium	19.9		28.9		19.7		16.5		17.3		19.5	
Large/Giant	20.2		29.4		22.3		15.6		16.1		20.0	
If bitten, most recent dog bite												
<1 year	18.8	0.716	27.9	0.752	25.5	0.460	15.2	0.269	17.2	0.331	20.0	0.271
1 - <3 years	26.9		21.2		22.7		16.0		15.9		17.8	
3 - <6 years	27.8		32.9		28.5		19.1		17.5		27.0	
6 - <10 years	19.1		24.7		17.4		17.8		17		19.2	
≥10 years	20.0		28.2		21.0		16.1		18.2		19.9	
Dog related safety Training												
Yes	17.1	**0.002**	20.2	**0.025**	16.7	**0.002**	16.1	**0.020**	15.6	**<0.001**	17.1	**<0.001**
No	28.5		32.0		27.3		19.7		19.9		26.8	

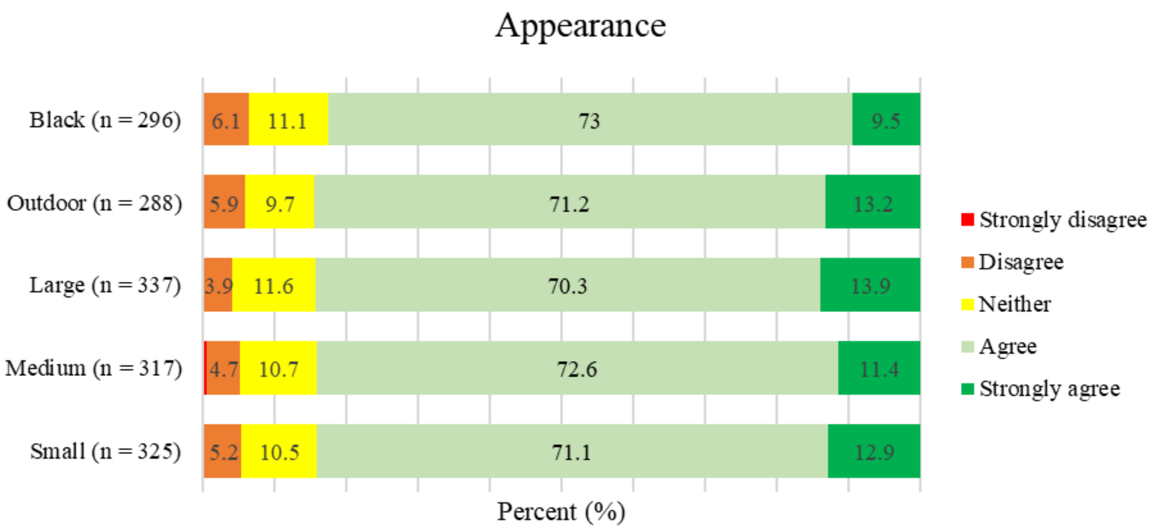
Appendix 7.5 Participants perceived meaning of different dog behaviours. (Note: values <2% are not shown)

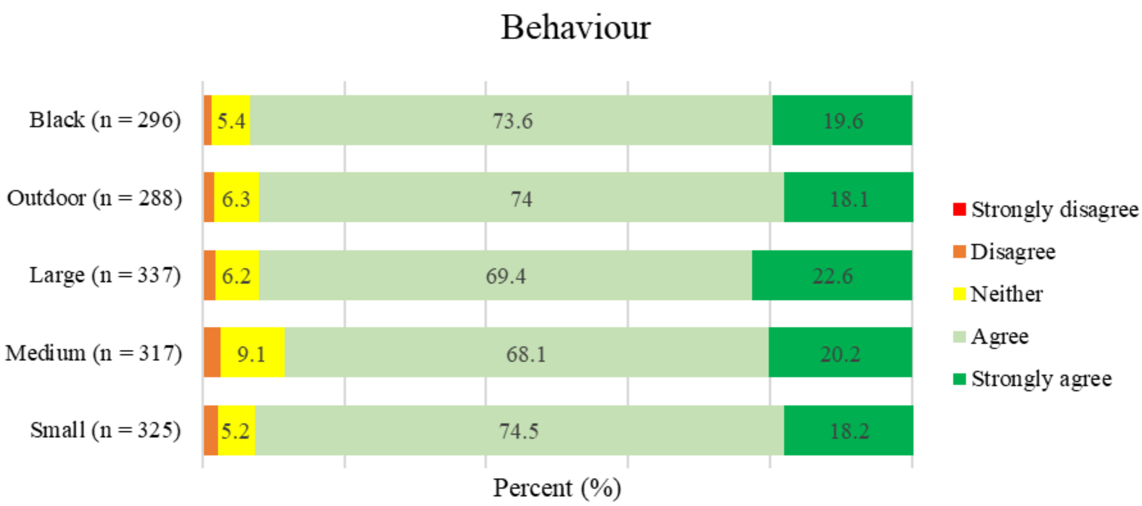


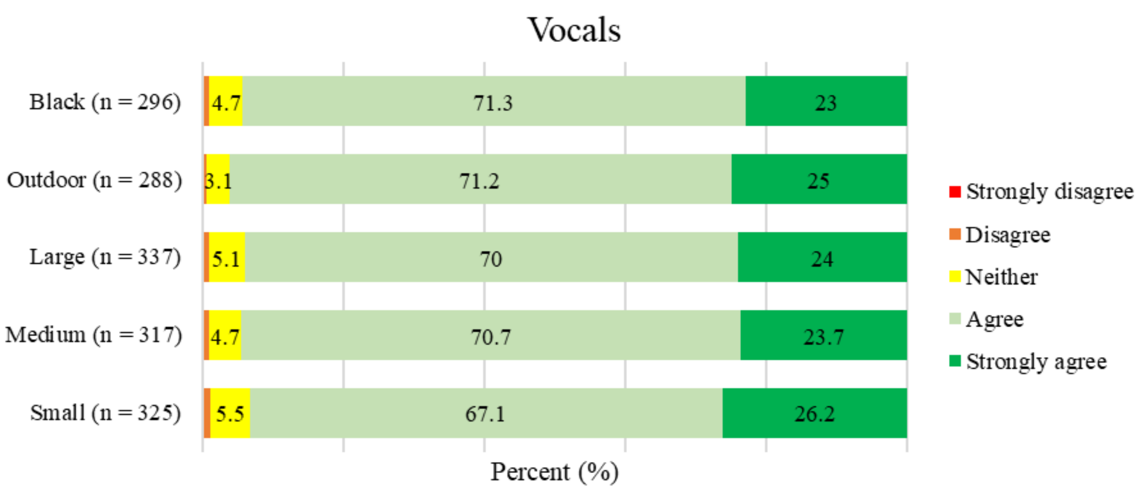


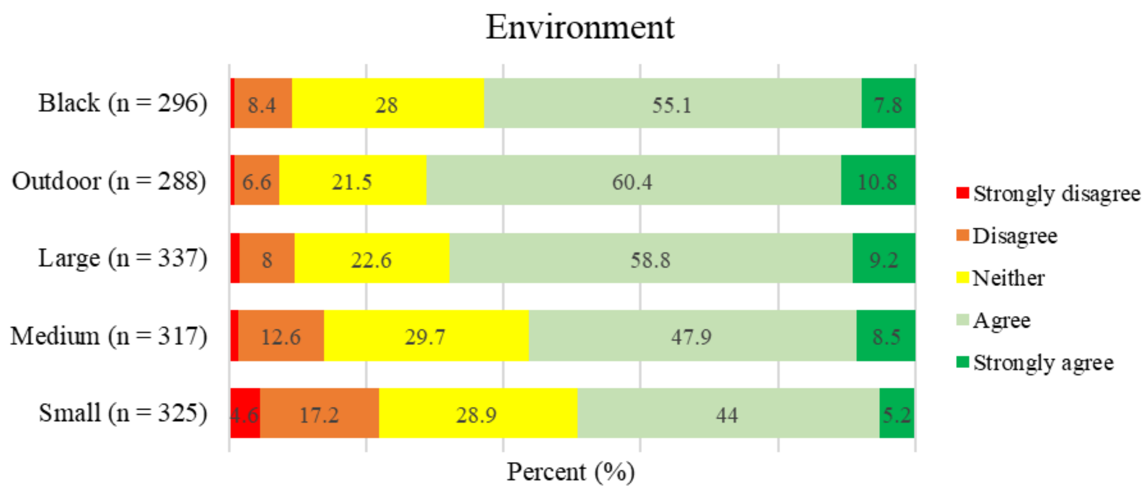


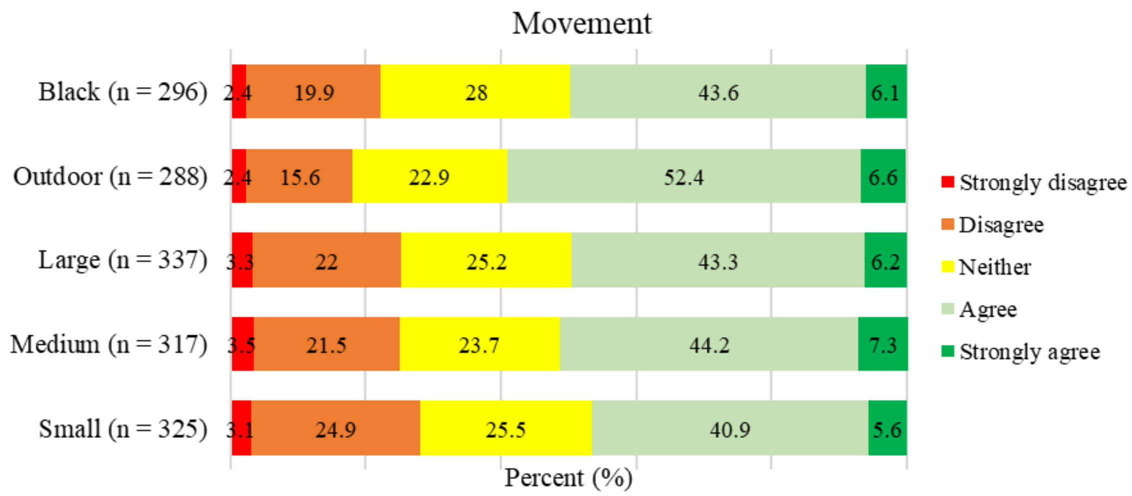
Appendix 7.6 Agreement with the statements that behaviour, appearance, vocals were 'like that of a real dog' and the environment was 'like that of the real world' and movement was 'like that of human movement'.








Environment
Black (n = 296)
Outdoor (n = 288)
Large (n = 337)
Medium (n = 317)
Small (n = 325)
8.4
28
55.1
7.8
6.6
21.5
60.4
10.8
8
22.6
58.8
9.2
12.6
29.7
47.9
8.5
4.6
17.2
28.9
44
5.2
Percent (%)
Strongly disagree
Disagree
Neither
Agree
Strongly agree


Movement
Black (n = 296)
Outdoor (n = 288)
Large (n = 337)
Medium (n = 317)
Small (n = 325)
2.4
19.9
28
43.6
6.1
2.4
15.6
22.9
52.4
6.6
3.3
22
25.2
43.3
6.2
3.5
21.5
23.7
44.2
7.3
3.1
24.9
25.5
40.9
5.6
Percent (%)
Strongly disagree
Disagree
Neither
Agree
Strongly agree

CHAPTER 8. A PILOT STUDY OF FIRST-YEAR VETERINARY STUDENTS' KNOWLEDGE AND INTERPRETATION OF AGGRESSIVE DOG BEHAVIOUR USING VIDEOS OF A SIMULATED DOG MODEL BEFORE AND AFTER A TEACHING AND HANDLING SESSION

[This chapter is now published: Oxley, J. A., Meyer, G., Butcher, M., Bellantuono, G., Levers, A. and Westgarth, C. (2024). Veterinary students' proximity to and interpretation of a simulated "aggressive" dog before and after training. *Scientific Reports, 14,* 3209.]

8.1 Introduction

Veterinary visits are commonly reported to evoke stress and fear in dogs due to single or multiple stressors e.g. a previous negative experience, auditory/olfactory stimuli, pain, unfamiliar animals/people, restraint, close contact, etc. (Döring *et al*., 2009; Riemer *et al*., 2021; Kartashova *et al*., 2021). Indeed, such scenarios may result in a fight, flight, or freeze response and in cases of a perceived imminent threat that cannot be avoided (i.e., in a consultation room, being restrained on a table) these options are further reduced to fight and freeze. In such scenarios, behaviours indicative of increasing levels of emotional arousal, often associated with fear, may be displayed such as lip licking, head turn, yawning, paw raise (Shepherd, 2009). However, previous research has found that in a survey of Spanish veterinary students (Menor-Campos *et al*., 2022) and dog owners (Mariti *et al*., 2012) both were less accurate at recognising signals such as yawning, lip licking, turning their head as indicators of stress compared to other signals e.g. growling, snapping, which were perceived to be stronger indicators of stress in dogs.

Given the subjective and broad nature of the terms 'aggressive' and 'aggression' it is important that the authors provide a definition (Mills *et al*., 2017, p. 13). For the purposes of this study the term aggressive was defined as a group of behaviours which are displayed by a dog in response to a perceived threat by human or conspecific (also known as social aggression Luescher and Reisner, 2008), motivated by a negative affective state (e.g. fear, stress, anxiety), also known as affective aggression, in order to preserve itself and avoid injury or harm. In a context where a dog cannot escape (e.g. a consultation room or corner of a living room), multiple behavioural signals indicating that the dog is uncomfortable with an approaching perceived threat are initially displayed (e.g. lip lick, yawning, head turn, paw raise, backing away). These signals are displayed in an effort to increase the distance between itself and the perceived threat in order to avoid direct confrontation and injury. If the threat continues, the intensity of the motivational response and behaviours increases to the point where the dog is indicating that they are now direct threat which may include crouching, showing teeth, growling, snapping and finally a bite. The authors refer to the CLA model as an example (Shepherd, 2009).

Dogs that display aggressive behaviour are a concern to veterinary staff and owners due to the potential for dogs to bite causing minor to severe injury and in rare cases death (Singh and Malik, 2014). Such incidents may result in time off work, treatment/surgery, infection and/or zoonotic disease transmission all of which have potential legal and financial implications (Nienhaus *et al*., 2005; Singh and Malik, 2014; Pugliese *et al*., 2019). Of course, fear itself is a welfare concern for the individual animal and efforts need to be considered to address this e.g. veterinary practice layout optimised (Greenfield, 2013) and low-stress handling (Riemer *et al*., 2021). In addition, the initial purpose of the veterinary visit could also be due to a pre-existing canine behaviour problem (Hevern, 2022).

Occupational injuries to veterinarians and other veterinary staff, such as animal bites, are commonplace and have even been referred to as being "part of the job" (DVM360, 2020). Nienhaus *et al*. (2005) found that, in Germany, veterinary staff were 2.9 times more likely to suffer a work-related injury in comparison to medical staff. Furthermore, they also found that over half (59.7%, 1,077/1,805) of work-related injuries to veterinary staff were due to animals causing cuts, bites or scratches. Injuries to veterinarians and veterinary staff due to 'bites', 'dog and cat bites' or 'bites, scratches or cuts' have been reported as one of the most common within veterinary practices in Australia (Jeyaretnam *et al*., 2000; Lucas *et al*., 2009), USA (Landercasper *et al*., 1988), India (Mishra and Palkhade, 2020) and Canada (Epp and Waldner, 2012). The British Veterinary Association (2015) found that 62% (292/474) of veterinarians surveyed suffered a work-related injury in the past twelve months. Of the companion animal vets (251/292), the majority (75%, 188/292) said they had been bitten by an animal, the second highest injury type reported among companion animal veterinarians (BVA, 2015).

Mannion *et al*. (2016) found that 87% of veterinary students thought it likely that they would be bitten by a dog during their veterinary career. Indeed, Landercasper *et al*. (1988) found that 92.3% of veterinarians from the US states of Minnesota and Wisconsin had received a dog bite during their veterinary career. More recently, Fritschi *et al.* (2006) found that 48% of 2718 Australian veterinarians received a dog bite or scratch resulting in a puncture to the skin within the past 12 months. Interestingly, of these, veterinarians who graduated between 1990 and 2000 were 2.55 times (CI95% 1.86 – 3.50) more likely to be bitten in the last 12 months compared to veterinarians that had graduated between 1960 and 1969. It is possible that this discrepancy is related to the relative clinical experience of the veterinarians which may be a factor in dog bite prevention in a clinical setting.

Previously, in the UK, according to Mannion *et al*. (2016, p. 536) *"most veterinary students and veterinary school curricula do not have any formal teaching in the assessment and recognition of dog behaviour or of the signs of canine aggression"*. However, it is unclear if this remains to be the case in the UK. Recently, Kogan *et al*. (2020) surveyed US veterinarians and found that despite almost all (99.6%) participants seeing behavioural cases in practice, less than half (43%) of veterinarians felt they received enough animal behaviour training during veterinary school, whilst 39% and 18% stated they received a few hours and none respectively. Furthermore, veterinarians most frequently reported being uncomfortable or very uncomfortable when dealing with behavioural problems including human-directed aggression and 'fear biting'.

Therefore, the importance of investigating the effectiveness of the teaching and assessment of veterinary students' knowledge and understanding of canine behaviour, including both normal and abnormal behaviour, is threefold. Firstly, accurate knowledge and the ability to differentiate between normal and abnormal canine behaviour is important in identifying any potential health and welfare-related factors associated with illness or poor health e.g. aggression due to pain (Sherman and Serpell, 2008). Secondly, as with the public, appropriate knowledge of canine behaviour is likely to indicate if the dog wants to be approached and the veterinarian's behaviour and method of approach and handling can be adjusted accordingly (Sherman and Serpell, 2008) and this is important for the safety of the veterinary staff, owners and dogs. Thirdly, canine behavioural knowledge is fundamental in the prevention, diagnosis, and appropriate treatment (or referral), of behavioural problems (Lilly *et al*., 2020).

The present study aimed to use an online survey with videos to:

i. Assess veterinary students perceived safest proximity to approaching an aggressive and non-reactive simulated dog.

   Hypothesis 1: Veterinary students will move significantly closer to the non-reactive dog in comparison to the dog displaying aggressive behaviour.

ii. Compare the difference in students perceived safest proximity to both the aggressive and non-reactive simulated dog, prior to and after a teaching intervention about canine behaviour and a handling practical class.

   Hypothesis 2: Veterinary students will stay further away from the dog displaying aggressive behaviour in the post-intervention survey compared to the pre-intervention survey.

iii. Compare the difference in perceived safest proximity between the intervention group (see aim 2) and a control group that has not received the teaching intervention.

   Hypothesis 3: The control groups will get closer to both the aggressive and non-reactive dogs compared to the intervention group.

iv. Assess participants' recognition and interpretation of behaviours based on the Canine Ladder of Aggression model, prior to and after the teaching intervention and compare to a control group assessed twice pre-intervention.

   Hypothesis 4: Students will be less likely to recognise the signals displayed by the virtual dog early in the aggressive scenario (e.g. lip licking, yawning) than those displayed by the dog later in the sequence of behaviour (e.g. showing teeth).

v. Examine the recognition and the perceived safest proximity to the dog by the student's related experience.

   Hypothesis 5: Those who have been previously bitten by a dog and/or have less frequent contact will show a reduction in approach-stop time in comparison to those who have not been previously bitten and/or have more contact with dogs.

vi. Assess the realism of the appearance and presence of the virtual dog model.

   Hypothesis 6: The majority of participants will agree that the dog model's appearance and behaviour are realistic.

8.2 Method

8.2.1 Participants

8.2.1.1 Recruitment

A total of 209 first-year veterinary students were enrolled on the BVSc degree (academic year: 2020 – 2021) at the University of Liverpool. At the start of the degree, students were allocated into seven groups, six with 30 students and one with 29, for their practical sessions.

Students were allocated into two study groups based on the time of their practical handling teaching sessions that occurred for each group. Both the control (n = 90) and intervention (n = 119) groups were sent the first survey by email between 18th and 19th December 2020 and a reminder on the 4th January 2021, before any teaching sessions occurred (Figure 8.1). The second survey (Survey 2) for the control group was sent out on the 11th of January and a reminder on the 14th January 2021 which was again before any teaching sessions had taken place. The intervention group was sent survey two the week after their final practical teaching session which occurred between mid-February and early March 2021. As the survey was entirely voluntary, to maximise completion, a follow-up reminder between 1-2 weeks after the invitation was sent. Given the low response rate for the intervention group, the control group were invited to complete a third survey (post-intervention) on the 19th February 2021, after they had attended their practical/teaching session, and a final reminder was sent on the 9th March 2021. The control group participants who completed the first and third survey were added to the intervention group for sub-analyses to increase the sample size and are hereafter referred to as the 'combined intervention group' (Figure 8.1). (see surveys here: https://tinyurl.com/JOxleyPhDDigital).

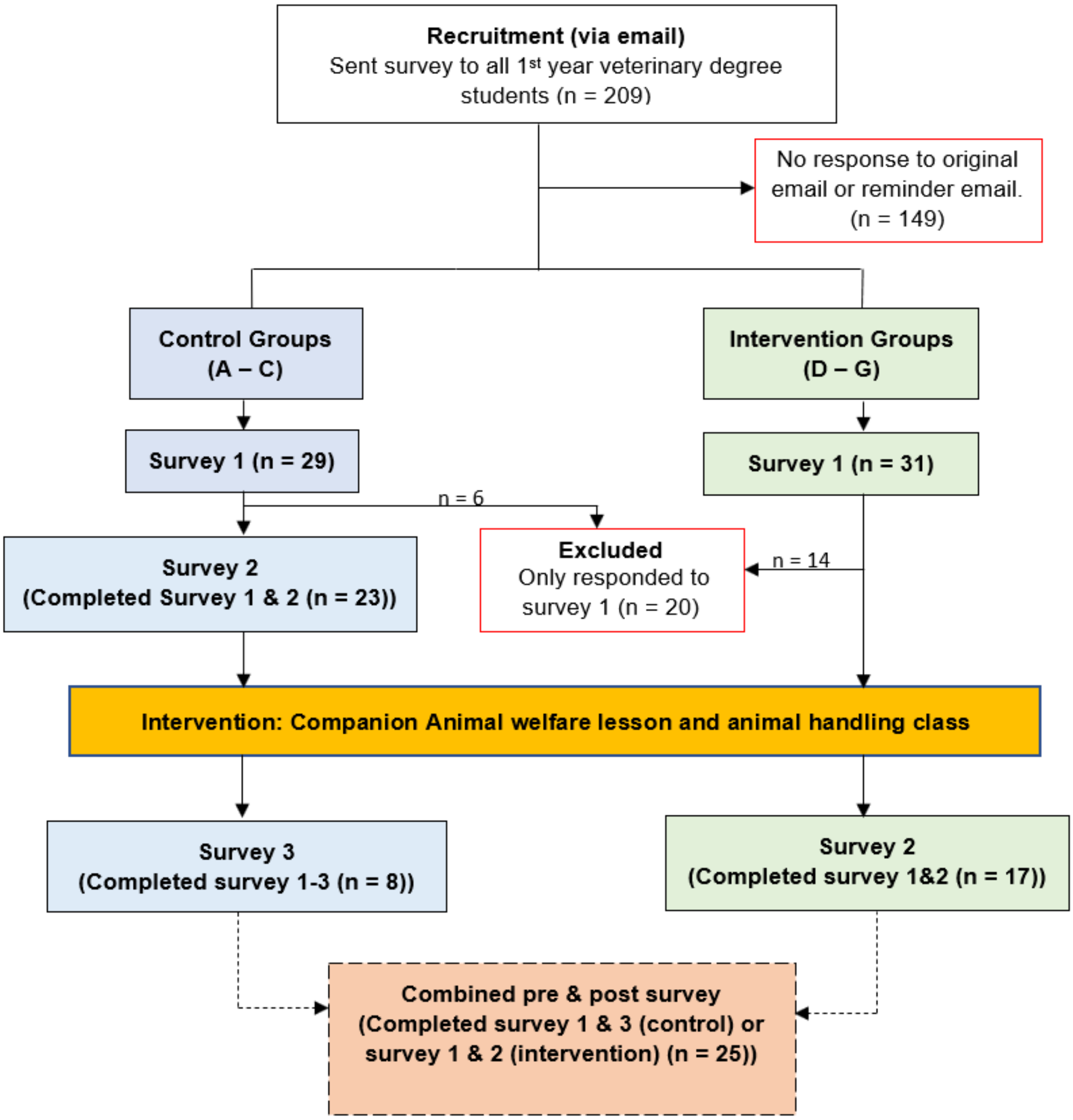


Figure 8.1 Recruitment and participation flowchart of veterinary students.

8.2.1.2 Sample size

A priori analysis in G*power was conducted using an ANOVA repeated measures (power = 0.80, medium effect size = 0.25; α = 0.05) and determined that a minimum total sample of 34 (17 per group) was required (Faul *et al.*, 2007).

Overall, a total of 40 out of the 209 veterinary students (19.1%), completed both the survey 1 and 2. This included a control group (n = 23) and an intervention group (n = 17) (Figure 8.1). Eight of the control group also completed the third survey post-intervention wait-list, which when added to the intervention group findings resulted in 25 participants with data for pre-post intervention.

8.2.2 Ethics

This study was approved by the University of Liverpool’s Veterinary Research Ethics Committee (VREC1042/VREC1042a) and conducted in compliance with the Declaration of Helsinki.

8.2.3 Online survey

Online questionnaires were developed and then reviewed by two veterinary behaviourists; both were qualified veterinary surgeons (RCVS) and Certified Clinical Animal Behaviourists, and one was a European Veterinary Specialist in Behavioural Medicine. As a result, the questionnaire was subsequently updated, and the final version was approved by the year lead for first-year Bachelor of Veterinary Science (BVSc). The survey was hosted by the online software Gorilla Experiment Builder (www.gorilla.sc) (Anwyl-Irvine *et al*., 2020). The online survey was completed by participants voluntarily as this was not a compulsory part of their degree.

The survey was presented multiple times to participants over the study period. At the start of the first survey, an information page covered the purpose of the research, voluntary participation, inclusion criteria (first-year veterinary students), ethical approval and researcher contact information. It was recommended that the survey be taken on a PC or laptop with the sound on at a normal level. All participants were required to confirm they had read and understood the reasons for the research and agree to take part. Inclusion criteria were confirmed by compulsory questions at the beginning of the survey. In the recruitment email, all participants were provided with an ID number to submit in order to pseudo-anonymise the surveys and allow different time points to be connected.

The survey included four sections. Section one part A was only conducted in the first survey and included questions relating to veterinary student demographics (gender, age, education level), dog ownership (previous/current and length of ownership), dog-related experience (contact with non-owned dogs, dog-related job or hobby), previous experience of being bitten (causing bruising or puncture to the skin (Oxley *et al*., 2019)), previous canine behaviour courses taken. Both the first and second surveys then enquired in section one part B about the amount of formal teaching students had received about canine behaviour so far during the BVSc degree, confidence in their ability to interpret canine behaviour (ordinal scale; 1 = not at all confident to 5 = very confident), and agreement to six statements (five-point Likert scale; strongly agree to strongly disagree) including three questions related to an individual's feelings in the presence of a dog, and three questions about their perceived ability to recognise aggressive, relaxed and scared/fearful dog behaviours.

Section two included two video tasks consisting of an aggressive and non-reactive dog model. Each participant was shown both videos but in a random order so that potential order effects were taken into account. The reactive dog model and behaviours were based on the Canine Ladder of Aggression model (Shepherd, 2009) (Chapter 1.3) and the environment (an indoor living room) was the same as those used in the previous virtual reality task (Chapter 4; Oxley *et al.*, 2022). The aggressive dog model consisted of 6 different levels. At level 0 the dog was lying down until user movement started in which case the dog stood up. The behavioural signs from the dog in the scenarios labelled as aggressive were categorised into zones 1, 5, 6, 7, 8 according to how far into the behavioural sequence, in time, they occurred. Level 2, 3 and 4 did not occur as these levels were only activated if the user was stationary and therefore was not applicable in this video due to the continuous movement. Behaviours in zone one included signs such as the dog taking a step backwards, standing and moving head upwards and yawning and lip licking. In contrast, zone 8 included signs such as the dog crouching, baring teeth, eyes widened with whites of the eye visible, lip lick and growling (see Appendix 6.1 for levels and behaviours). In the non-reactive video, the dog behaviour included standing up, looking left and right sniffing the ground, sitting with mouth open and a relaxed tail, and taking a step forward (see Chapter 3). The non-reactive dog video was shorter in length (48.6s) compared to the aggressive dog (56.6s), as the aggressive dog moves backwards, and the non-reactive dog does not. The purpose of the task in each video was to ascertain the proximity participants get to the dog model.

In this study, the movement in the videos was not controlled by the user and consisted of a consistent speed from the start to the end of the videos. Participants were instructed to

*"*Once the video starts, *press the STOP button at the point that you would stop, IF you would stop approaching the dog before the end of the video. Please click the video to start. A countdown to the video will occur".*

Section three involved asking participants to now watch a full video of the aggressive dog. Questions were then asked if they noticed any vocalisations and perceived emotions of the dog, what they noticed in general about the dog's behaviour, and if they noticed specific behaviours (lip lick, yawning, paw raise, head turn, backing away and showing teeth) and their perceived meaning for each behaviour. Section four included the Igroup Presence Questionnaire which consisted of 14 questions (Schubert *et al*., 2001). Once completed, a debrief information sheet was displayed informing them of the study information, how data will be used and study contact information.

8.2.4 Interventions

There were two main educational interventions which were included as part of this study and were part of the BVSc course. The first intervention included a Companion Animal Welfare lesson taught to a single class, including all students, on the 15th January 2021. The lesson included relevant topics relating to indicators of fearful and aggressive behaviour in dogs. Specific references and descriptions were made to the Canine Ladder of Aggression model and three YouTube videos were used to discuss the body language of a fearful dog.. The YouTube videos discussed in the lesson are as follows:

- Video 1 – 'Guilty look' (https://www.youtube.com/watch?v=gpMemo9CWrI)
    - Length: 54 seconds
    - Behaviours displayed: lip lick, yawn, side eye (whale eye), raised paw.
- Video 2 – Police dog bites reporter (https://www.youtube.com/watch?v=PHLnjiISsOo)
    - Length: 2 minutes 57 seconds
    - Behaviour displayed: Lip licking, side eye (whale eye), ears back, direct eye contact, crouched/lower body posture, lunge, bite.
- Video 3 – Fear behaviours in dogs (https://www.youtube.com/watch?v=Fq1LdD4MJnk)
    - Length: 4 minutes 10 seconds
    - Behaviour displayed: Lip licking, yawning, moving back, crouched/lower body posture, snarling, growling, snapping.

The second intervention included the handling of animals course (HACS) which included multiple online lectures (due to COVID) and further resources to read/watch plus a 2-hour in-person handling practical on the handling of dogs and cats. A component of the HACS teaching involved a lecture delivered by a veterinary behaviourist focused on recognising the range of independent behavioural responses to protective (negative) emotions in dogs and discussed how this leads to an individualised approach to dogs in a clinical context.

8.2.5 Statistical analysis

All data were exported from the online survey software Gorilla Intervention Builder into Excel. Statistical analysis was conducted in Microsoft Excel (Microsoft Office 365, Microsoft Corp.) and SPSS (version 27, IBM, Armonk, NY: IBM Corp). Descriptive statistics were summarised and presented in percentages. For both ordinal (confidence scale) and continuous (time taken to stop the videos) data the Wilcoxon signed-rank test was used for within group (pre-post surveys) and the Mann-Whitney U tests for between group (control versus intervention) comparisons. Pre-post change per group was calculated by subtracting the pre-survey approach stop time from the post-survey approach stop time and the size effects were calculated ($z/\sqrt{N}$) (Pallant, 2016). A Kruskal-Wallis test was used to assess if there was a difference in approach stop time based on the frequency of contact with dogs. Recognition of behaviours (e.g. lip lick = yes or no) between survey 1 and survey 2 was analysed for both the control and intervention group using McNemar’s test. A p-value of <0.05 was considered significant. Open-ended questions related to the meaning of dog behaviours were coded into themes using the qualitative statistical software Nvivo Pro (version 12, 2020, QSR International Pty Ltd.). Boxplots were created in the software Origin (2020b, OriginLab Corporation, Northampton, MA, USA).

8.3 Results

8.3.1 Participant demographics

Most participants were female (92.5%), which was a higher proportion of females compared to the overall class (84.2%; 176/209). There was no difference in age between the control and intervention groups ($U = 163.0$, $p = 0.386$) (Table 8.1). Most participants currently owned a dog and had owned a dog for nine years or longer. Seventy per cent of participants currently or previously worked with dogs (either voluntarily and/or paid) (Table 8.1). Regarding dog bites causing bruising or puncture to the skin, 35% of participants in both the control and intervention group reported having been previously bitten.

Table 8.1 Participants' demographics and dog-related experience.

	Control (*n* = 23) n (%)	**Intervention (*n* = 17) n (%)**	**Total (*n* = 40) n (%)**
Age - mean years (range)	19.9 (18-25)	20.7 (18-39)	20.2 (18-39)
Gender			
Female	22 (95.7)	15 (88.2)	37 (92.5)
Male	1 (4.3)	2 (11.8)	3 (7.5)
Dog ownership			
No	2 (8.7)	4 (23.5)	6 (15.0)
Yes, previously	3 (13.0)	1 (5.9)	4 (10.0)
Yes, currently	18 (78.3)	12 (70.6)	30 (75.0)
Length of dog ownership			
9 years or longer	15 (71.4)	11 (84.6)	26 (76.5)
7 - <9 years	1 (4.8)	0	1 (2.9)
5 - <7 years	1 (4.8)	1 (7.7)	2 (5.9)
3 - <5 years	2 (9.5)	0	2 (5.9)
1 - <3 years	1 (4.8)	1 (7.7)	2 (5.9)
<1 year	1 (4.8)	0	1 (2.9)
Frequency of contact with dogs (other than owned dogs)			
At least once a day	3 (13.0)	1 (5.9)	4 (10.0)
Several times a week	10 (43.5)	6 (35.3)	16 (40.0)
Several times a month	7 (30.4)	6 (35.3)	13 (32.5)
Less than once a month	3 (13.0)	4 (23.5)	7 (17.5)
Current/previous work with dogs			
Yes	16 (69.6)	12 (70.6)	28 (70.0)
No	7 (30.4)	5 (29.4)	12 (30.0)
Current/previous hobby with dogs			
Yes	3 (13.0)	3 (17.7)	6 (15.0)
No	20 (87.0)	14 (82.3)	34 (85.0)
Previously bitten (causing at least bruising or skin puncture)			
Yes	8 (34.8)	6 (35.3)	14 (35.0)
No	15 (65.2)	11 (64.7)	26 (65.0)

8.3.2 Dog related statements

Participants were asked to complete the six dog-related statements on both the survey 1 and 2. In both surveys, over 90% of all participants agreed with the statements regarding enjoying and feeling relaxed in the presence of most dogs and perceived ability to recognise 'relaxed', 'aggressive' and/or 'scared/fearful' behaviour (Appendix 8.1). Participants were also asked about the current veterinary degree and the learning of the concept of canine behaviour and how much teaching they had received about canine behaviour (Table 8.2).

Table 8.2 Participants' responses to questions relating to introduction to the concept of canine behaviour and the formal teaching of canine behaviour so far.

	Control			Intervention		
So far, during your veterinary degree, have you been introduced to the concept of canine behaviour?	**Survey 1 n (%) (n = 23)**	**Survey 2 n (%) (n = 23)**	**p-value**	**Survey 1 n (%) (n = 17)**	**Survey 2 n (%) (n = 17)**	**p-value**
Yes	8 (34.8)	11 (47.8)	0.250*	4 (23.5)	16 (94.1)	<0.001*
No	14 (60.9)	12 (52.2)		12 (70.6)	1 (5.9)	
I don't know	1 (4.3)	0		1 (5.9)	0	
So far, during your veterinary degree, approximately how much formal teaching in canine behaviour have you received?						
Not at all	18 (78.3)	14 (60.9)	0.221**	11 (64.7)	0	0.003**
Half a day or less	5 (21.7)	8 (34.8)		6 (35.3)	9 (52.9)	
1 day	0	1 (4.3)		0	5 (29.4)	
≥2 days	0	0		0	3 (17.7)	

*McNemar's test using yes (1) and no (0) values only.

**McNemar's test using formal teaching (1) or no formal teaching (Not at all) (0).

8.3.3 Perceived virtual dog appearance and behaviour

Most participants (≥80%) agreed with the two statements stating that the appearance and behaviour of the dog was similar to that of a real dog in both the non-reactive and aggressive videos (Appendix 8.2).

8.3.4 Self-rated confidence

There was a significant increase in the self-reported confidence rating relating to a respondent's ability to interpret canine behaviour between survey 1 (pre-intervention 1) and 2 (pre-intervention 2) in both the control group (Z = -2.546; p = 0.011; *r* = 0.4) and the intervention group (Z = -2.972; p = 0.003; *r* = 0.5) (Table 8.3 and Appendix 8.3). A significant increase in confidence ratings was also evident between survey 1 and survey 2 of the combined intervention group (Z = -3.252, p = 0.001; *r* = 0.7). Thus, there was no difference in the change in scores (between survey 1 and 2) between the control and intervention group (p = 0.516) as all groups increased in confidence (Table 8.3).

8.3.5 Approach-stop task

8.3.5.1 Within-group comparison: non-reactive compared to the aggressive scenario

In both the control and intervention group, participants spent significantly longer (p<0.001) approaching the non-reactive dog (i.e. they got closer) compared to the aggressive dog (Figure

8.2) (despite the shorter length of the video). This was also the case for Survey 3 (combined intervention group) for both the pre ($p<0.001$) and post-survey ($p<0.001$).

8.3.5.2 Within-group comparison: pre-compared to post-intervention

In the aggressive scenario, there was a reduction in the approach-stop time from survey 1 (Md = 17.8s) to survey 2 (Md = 15.2s) in the intervention group (Z = - 2.367; p = 0.018; *r* = 0.4) and the combined intervention group (survey 1 (Md = 15.8s), survey 2/3 (Md =15.1s); Z = -2.153; p = 0.031; *r* = 0.4), but not in the control group (p = 0.417) (Table 8.3). There was no difference in approach-stop times between survey 1 and 2 in the non-reactive scenario in the control (p = 0.376), intervention group (p = 0.156) (Table 8.3) or combined intervention group (p = 0.362).

8.3.5.3 Between-group comparison: change pre-post intervention

There was no evidence of a significant difference in pre-post change in approach-stop times between control and intervention groups for the non-reactive scenario (U = 164.5, p = 0.401). In the aggressive scenario there was a significantly larger pre-post change in approach-stop times in the intervention (Md = -2.1s) group compared to the control group (Md = -0.2s) (Z = -2.491; p = 0.012) (Table 8.3).

8.3.6 Approach-stop time and dog-related experience

The was no evidence of a difference in approach-stop times towards the dog displaying aggressive behaviour between individuals that had and had not been previously caldebitten in both the control (survey 1: p = 0.286; survey 2: p = 0.582) and intervention group (survey 1: p = 0.651; survey 2: p = 0.131). There was also no evidence of a difference between approach-stop times based on the frequency of contact with dogs in the control (survey 1: p = 0.074; survey 2: p = 0.065) and intervention group (survey 1: p = 0.794; survey 2: p = 0.200).

8.3.7 Timing of approach-stop task in relation to canine behaviours displayed

Most participants activated the stop button when the dog's behaviour was within zone 1 in both the control (survey 1: 95.7%, 22/23; survey 2: 87.0%, 20/23 (Z = -1.342; p = 0.180)) and the intervention group (survey 1: 82.4%, 14/17; survey 2: 100%, 17/17 (Z = -1.633; p = 0.102)). The highest zone of behavioural responses that any participant reached before activating the stop button was level 6 out of the 8 levels. The median stopping time for participants who stopped in zone 1 was 15.2s (standing and moving head upwards) post-intervention (survey 2) compared to 16.0s (dog standing still looking at the user) pre-intervention (survey 1). In the control group median stopping time for participants who stopped in zone 1 in survey 2 was 14.6 seconds (dog takes a step backwards) compared to 15.2s (dog takes a step backwards and raises its head) in survey 1.

Table 8.3 Pre-post change in confidence ratings and approach stop times within the control and intervention groups. (Note: this table does not include the combined intervention group).

Measure	Median (Control)	Median (Intervention)	Control/Int. Comparison of change
Confidence			
Pre-intervention 1	3 (2 to 5)	3 (1 to 4)	
Pre-intervention 2	4 (3 to 4)	4 (3 to 5)	
Change	0.5 (-1.0 to 3.0)	1 (0 to 2)	
p-value	**0.011**	**0.003**	0.516
Approach-stop task (time)			
Non-reactive 1	31.4 (9.3 - 48.6)	42.8 (9.0 - -48.6)	
Non-reactive 2	31.4 (14.0 - 48.6)	31.7 (8.9 – 48.6)	
Change	0 (-19.8 - 11.0)	-0.1 (-28.5 - 17.7)	
P value	0.376	0.156	0.401
Aggressive 1	15.8 (11.2 - 37.3)	17.8 (14.5 - 36.1)	
Aggressive 2	15.0 (12.1 - 36.9)	15.2 (10.1 - 24.7)	
Change	-0.2 (-5.90 - 12.0)	-2.1 (-6.0 - 20.9)	
p-value	0.417	**0.018**	**0.012**

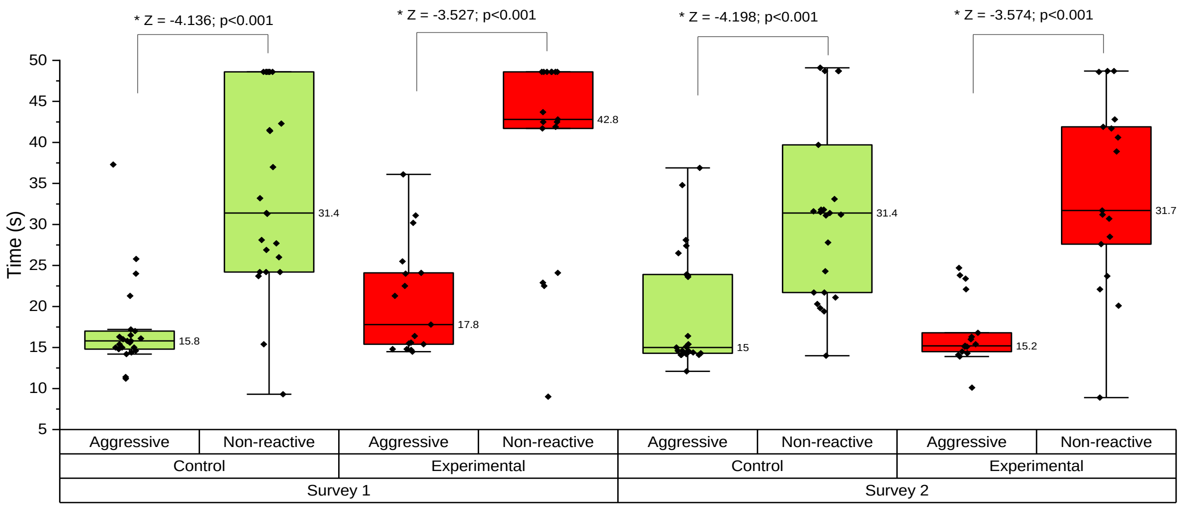


Figure 8.2 All approach-stop tasks for control and intervention groups in survey 1 and 2 and within group comparisons between the aggressive and non-reactive scenarios. Whiskers indicate values that are <1.5 times the interquartile range.

8.3.8 Recognition and interpretation of behaviours

Of the participants in both the control (n = 20) and intervention (n = 16) groups that completed the behavioural interpretation section in both surveys, the vast majority (>90%) stated that the emotions the dog was showing in the video were 'anxious' and scared/fearful' in both survey 1 and 2 (Table 8.4). Most participants (≥80%) in both control and intervention groups noticed growling and/or barking (Table 8.4).

Table 8.4 Types of emotions and vocalisations noticed by participants during the aggressive full-length video.

	Survey 1 Control n (%)	**Survey 2 Control n (%)**	**Survey 1 Int. n (%)**	**Survey 2 Int. n (%)**
What emotions do you think the dog was showing in the last video?				
Anxious	20 (100)	19 (95)	15 (93.8)	16 (100)
Scared/fearful	20 (100)	20 (100)	15 (93.8)	15 (93.8)
Anger	8 (40)	7 (35)	8 (50)	8 (50)
Sad/upset	5 (25)	5 (25)	5 (31.3)	2 (12.5)
Shy	4 (20)	3 (15)	3 (18.8)	4 (25)
Calm/relaxed	1 (5)	2 (10)	1 (6.3)	3 (18.8)
Total	20	20	16	16
Missing	3	3	1	1
Did you notice any dog-related sounds or vocalisations?				
Yes	20 (95.2)	20 (95.2)	16 (100)	15 (93.8)
No	1 (4.8)	1 (4.8)	0 (0)	1 (6.2)
Total	21 (100)	21 (100)	16 (100)	16 (100)
Missing	2	2	1	1
If yes, explain what [sounds or vocalisation] you noticed? (Multiple choice)				
Barking	20 (100)	18 (90)	14 (87.5)	12 (80)
Growling	17 (85)	19 (95)	15 (93.8)	15 (93.8)
Yawn/whining/whimpering	11 (55)	12 (60)	4 (25)	6 (40)
Panting	8 (40)	4 (20)	7 (44)	9 (60)
Snarling	3 (15)	3 (15)	3 (18.8)	3 (18.8)
Other*	2 (10)	2 (10)	3 (18.8)	2 (13.3)
Total	20	20	16	16
Missing	3	3	1	1

*Other: Lip licking (4), Yelp (2), Snapping (1), Grumbling (1), Squeaking (1)

All participants stated that they noticed the behaviours included in the higher time zones such as the dog moving backwards and showing their teeth (Appendix 8.4). In the control group, there was an increase, although not significant, in the reported recognition of three behaviours between survey 1 and survey 2 (including lip lick (75% to 95%), paw raise (65% to 90%) and head turn (75% to 95%). In the intervention group, the lip lick behaviour recognition increased from 50% to 87.5% pre and post intervention respectively ($p = 0.031$). In the context of the full video footage, the perceived meaning of lip lick, yawn and paw raise were, by the majority of participants, referred to as negative arousal or emotion (Appendix 8.5, 8.6 and 8.7). In the intervention group only, the term anxious to describe lip lick increased from 25% (4/16) in the pre-test (survey 1) to 50% (8/16) in the post test (survey 2) ($p = 0.125$).

8.3.9 Presence

There was no evidence of a difference between median presence ratings across both the control and intervention groups and within group pre and post surveys (Appendix 8.8).

8.4 Discussion

This study examined the effectiveness of a series of lectures and a practical lesson involving canine behaviour interpretation for undergraduate veterinary students, using an intervention and control group. It found that students from the intervention group reduced their approach-stop time (i.e. stopped further away) from a virtual dog showing aggressive behaviours post-intervention in comparison to pre-intervention. In contrast, the control group showed no evidence of change. Interestingly, there was no evidence of variation in approach stop distance depending on whether participants had previously worked with dogs, frequently had contact with dogs, or previously had been bitten by dogs, however sample sizes for these analyses were small and there may not have been power to detect any differences.

8.4.1. Confidence

Participant confidence in the interpretation of dog behaviour increased between survey 1 and survey 2. However, this was seen in both the control and intervention groups, so this may not be due to the intervention of the canine behaviour lessons. Similarly in the control group recognition of three behaviours increased between surveys 1 and 2. It could be argued that simply repeating the survey (i.e. practice effect) could increase participant confidence and behaviour recognition in the second survey especially as the same videos were used in both surveys 1 and 2. This demonstrates the importance of using a control group comparison in studies to identify the effect of an intervention on an assessment of behaviour in this way.

8.4.2 Vocalisations, emotions and behaviours

Barking and growling were the most recognised vocalisations after watching the full-length aggressive video. This is consistent with previous research, for example, Menor-Campos *et al*. (2022) found that excessive barking was most categorised as strongly related to behavioural stress indicators in fourth-year veterinary students.

Over 90% of participants stated that the emotion the dog was showing was anxious, scared or fearful. These emotions indicate that the participants were aware that the dog was showing some form of negative valence and high degrees of arousal (Mendl *et al*., 2010). However, the form of aggression in the present study was specifically defensive aggression often noted as a result of fear in response to a perceived threat (Haug, 2008). This may highlight that there is a lack of knowledge regarding specific terminology and if or how they differ in dog behaviour. For example, although there is likely to be some overlap, anxiety generally refers to the anticipation of a threat, that is not currently present, due to uncertainty (Bowen and Heath, 2005, p. 74). Fear, on the other hand, is the reaction to an actual or perceived threat which is present in the environment (Bowen and Heath, 2005, p. 73; Steimer, 2022). Further research would be useful to explore veterinary students' understanding of their perceived meanings and differences between such terms and if or how these could be applied to help understand defensive aggression in dogs.

In the approach-stop task, the majority of participants stopped in level 1 during which the dog was displaying signals of response to a potential perceived threat, including taking two steps backwards (occurred between 13.3s – 15.1s) followed by standing and staring directly at the user with a closed mouth and raised head (occurred between 15.1s – 20.3s). Large body movements have been previously identified when describing aggressive or fearful behaviours in dogs (Tami and Gallagher, 2009). A simple explanation could be as the dog is taking two steps backwards this could be interpreted as the dog trying to avoid or move away from the oncoming threat.

8.4.3 Realism of the dog model

It was encouraging to note that the majority of participants agreed that even a 2-D virtual dog model had similar behaviour and appearance to that of a real dog. This is likely due to multiple factors including the quality of the animation, and the behaviours displayed were based on realistic dog behaviour and reviewed by canine behavioural experts. This highlights the importance of collaboration between animation developers and dog behavioural experts (Oxley *et al*., 2022).

8.4.4 Limitations

In this case, the practicalities of the assessments (which had to be virtual due to COVID-19, and not impact teaching time) limited the study design. In future the surveys could be made compulsory as part of the lesson to ensure a larger sample size and avoid self-selection bias; for example, veterinary students with experience as a dog owner or with a particular interest in, or knowledge about, dogs being more inclined to complete the questionnaire. It is important to note that the question relating to confidence uses the broad term canine behaviour. It is possible that the mention of canine behaviour or aggression was briefly discussed during the curriculum outside of the specific interventions we were assessing. While the control group had not completed the formal teaching before survey 2, these students could have conducted independent research on the topic and thus increased their knowledge. It is also possible that after the first survey students could have discussed the survey and influenced each other's opinion or answers for the survey 2. In future research, more detailed questions could ask about students' formal and informal methods of acquiring knowledge on dog aggression. To avoid the potential for participants acquiring dog behavioural knowledge between surveys that are several weeks apart, it would be useful for the surveys to be administered directly before and after the taught and practical session and a final follow-up several weeks later to ascertain knowledge retention.

This study involved multiple teaching intervention components. The questions asked in the surveys were based on the CLA model terminology. Participants were offered options for the meaning of different behavioural signs based on that teaching. Various aspects of the Companion Animal Welfare and HACS course teaching discussed different terminology and other options for answering the questionnaire were not available. In future studies it could be beneficial to streamline teaching approaches and have questions relating to all approaches that the students are exposed to during teaching included in the survey.

The majority of participants had previously or currently owned, worked or had a hobby with dogs. This could have affected their ability to interpret dog behaviour and select a stop distance. Although similar to our findings, previous research found no relationship between pre-class animal behaviour knowledge and pet ownership in first year veterinary students (Lilly *et al*., 2020), attachment and bond of dog-owning students should be considered in future research as Menor-campos *et al.* (2022) recently found that attachment level was associated with higher identification of subtle dog stress signs (e.g., looking elsewhere and turning head) in veterinary students.

Furthermore, this study focuses on first year students only and in one of nine university veterinary schools in the UK at the time (BVA, 2022). Further research could expand to all veterinary students (years 1 – 5), qualified veterinarians and veterinary staff such as nurses, and technicians. Practical methods and course content for veterinary professional students will likely vary which could be assessed through a multi-site study.

Only three males completed both the survey 1 and 2, and therefore comparisons between gender were unable to be made. Previous research does highlight a similar gender bias in veterinary students' response rate (i.e. >90% female) (Calder *et al.,* 2017). However, gender comparison is of importance as male vets have been reported to be more likely to suffer bite injuries in comparison to females (Fritschi *et al*., 2006) and males have higher hospital admission rates in relation to dog bite injuries (Tulloch *et al*., 2021). However, Menor-Campos *et al*. (2022) stated that in an online survey, there were no differences between male and female veterinary students in their ability to recognise signs of stress in dogs.

In this study of veterinary students, two specific additions could be made. Firstly, additional questions to encourage the participant to think and discuss the possible options to deal with the dog's behaviour through interactive questions and options (e.g., attempt to restrain the dog, feed the dog treats). Secondly, additional virtual environments could be developed to resemble a veterinary practice or kennels allowing the student to undertake the video tasks in multiple environment types.

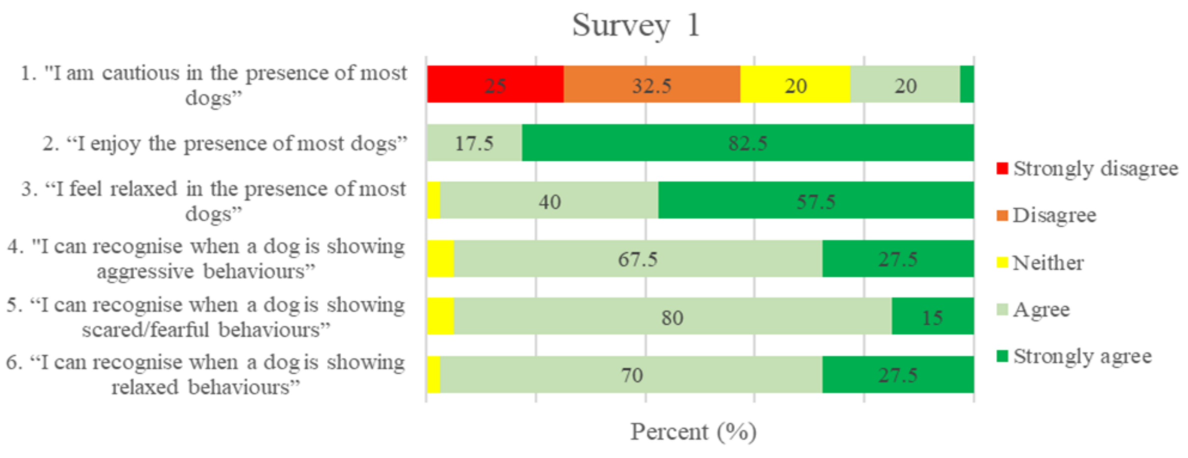
Finally, the online virtual approach stop task had limitations compared to actual virtual reality, including the user could not move backwards (away from the dog) after stopping. There was also no option for the user to remain stationary and offer for the dog to approach, as many may choose to do to reduce the risk of confrontation. Further development of the videos and the ability for the user to adjust the distance may be of use. In addition, comparisons between virtual reality and online surveys could be made to compare levels of immersion and realism and assess the potential difference in behaviour recognition and approach stop distances. Given the limitations, caution is needed when interpreting the results.

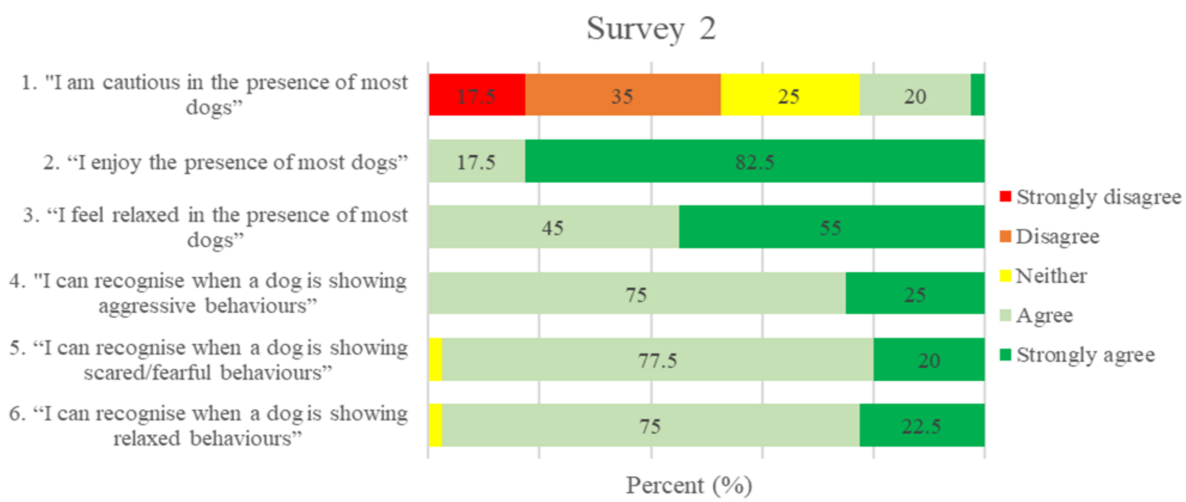
8.5 Conclusion

Most veterinary students agreed that the behaviour and appearance of the video of a virtual dog were similar to that of a real dog in both the non-reactive and aggressive videos. Between survey 1 and 2 there was evidence of a reduction in approach-stop time in the aggressive scenario for the intervention group but not the control group. This suggests that the veterinary students receiving canine behaviour and handling training did practice safer behaviour by reducing the approach-stop time when participating in the aggressive dog scenario. Furthermore, the approach-stop task appears to be a viable way to assess learning outcomes and potential behaviour change.

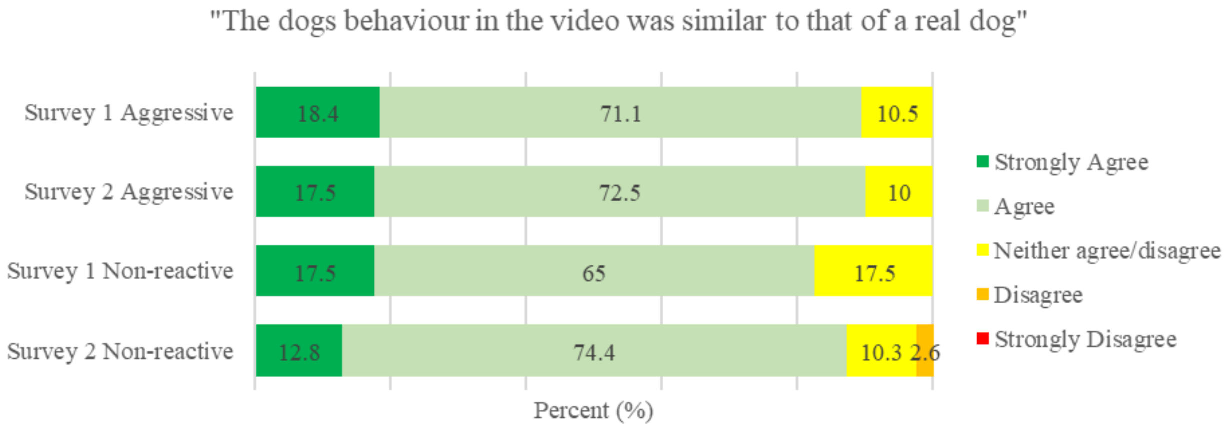
APPENDICES FOR CHAPTER 8

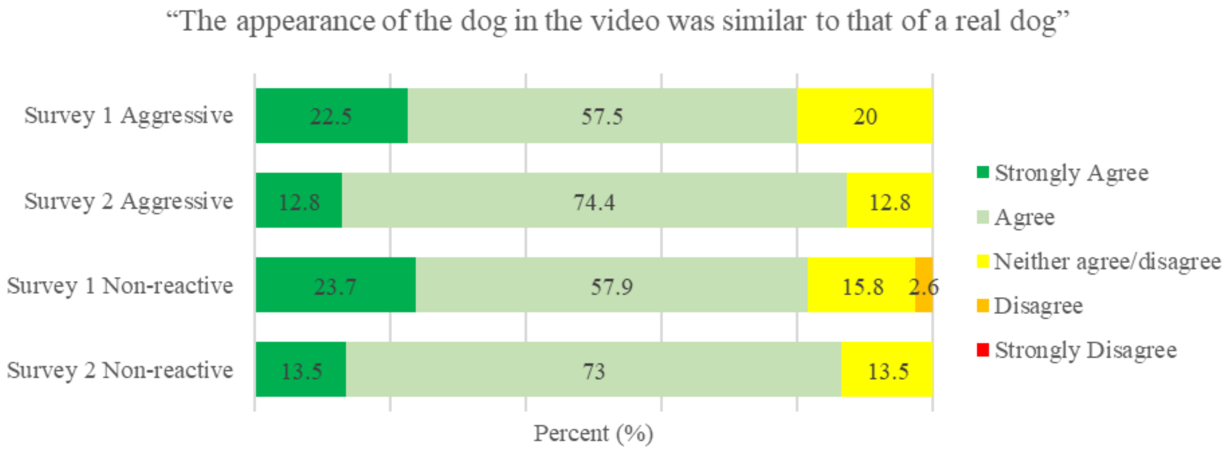
Appendix 8.1 Responses to six dog-related statements for survey 1 and survey 2.





Appendix 8.2 Participants' agreement with statements regarding the behaviour and appearance of the virtual dog compared to a real dog.





Appendix 8.3 Veterinary students responses to the question, "*Currently how confident do you currently feel in your ability to interpret canine behaviour?*". Ratings: 1 = Not at all, 2 = Slightly confident. 3 = Somewhat confident, 4 = Fairly confident, 5 = Very confident.

	Control Pre-intervention 1 (n = 23)		**Control Pre-intervention 2 (n = 23)**		**Intervention Pre-intervention 1 (n = 17)**		**Intervention Post-intervention 1 (n = 17)**	
Answer	n (%)	Mean (Median) (1-5)	n (%)	Mean (Median) (1-5)	n (%)	Mean (Median) (1-5)	n (%)	Mean (Median) (1-5)
Not at all confident	0 (0)	3.26 (3.00)	0	3.78 (4.00)	1 (5.9)	3.18 (3.00)	0	3.88 (4.00)
Slightly confident	5 (21.7)		0		2 (11.7)		0	
Somewhat confident	9 (39.1)		5 (21.7)		7 (41.2)		4 (23.5)	
Fairly confident	7 (30.4)		18 (78.3)		7 (41.2)		11 (64.7	
Very confident	2 (8.7)		0		0		2 (11.8)	

Intervention survey group (n = 17) combined with additional eight students who completed the first (pre) and third (post) survey from the control group (n = 25). Ratings: 1 = Not at all, 2 = Slightly confident, 3 = Somewhat confident, 4 = Fairly confident, 5 = Very confident.

Answer	**Pre-survey* n (%) (n = 25)**	**Mean (median) (1-5)**	**Post-survey n (%) (n = 25)**	**Mean (median) (1-5)**	**Wilcoxon, P value**
Not at all confident	1	3.16 (3.00)	0	3.92 (4.00)	Z = -4.146 P <0.001
Slightly confident	4		0		
Somewhat confident	10		5		
Fairly confident	10		17		
Very confident	0		3		

*Control group participants (n = 8) pre-survey data was from the first survey (survey 1).

A breakdown and comparison of the 'combined group' (n =25) including survey 3 of the control group (n = 8) and survey 2 of the intervention group (n = 17).

Answer	**Control Survey 3 n (%) (n = 8)**	**Mean (median) (1-5)**	**Intervention Survey 2 n (%) (n = 17)**	**Mean (median) (1-5)**
Not at all confident	0	4 .00 (4.00)	0	3.88 (4.00)
Slightly confident	0		0	
Somewhat confident	1 (12.5)		4 (23.6)	
Fairly confident	6 (75.0)		11 (64.7)	
Very confident	1 (12.5)		2 (11.8)	

Appendix 8.4 Behaviours seen in the full-length video task. *Only participants were included that completed the questions for both survey 1 and survey 2 in the control (n = 20) and intervention (n =16) groups.

	Survey 1 - Control (n = 20)			**Survey 2 - Control (n = 20)**			**McNemar's Test**
Behaviours	**Yes**	**No**	**Total**	**Yes**	**No**	**Total**	**P value**
Lip Lick	15 (75)	5 (25)	20	19 (95)	1 (5)	20	0.219
Yawn	16 (80)	4 (20)	20	15 (75)	5 (25)	20	0.625
Paw raise	13 (65)	7 (35)	20	18 (90)	2 (10)	20	0.754
Head turn	15 (75)	5 (25)	20	19 (95)	1 (5)	20	0.219
Backing away	20 (100)	0 (0)	20	20 (100)	0 (0)	20	-
Show teeth	20 (100)	0 (0)	20	20 (100)	0 (0)	20	-
	Survey 1 - Int. (n = 16)			**Survey 2 – Int. (n = 16)**			**McNemar's Test**
Behaviours	**Yes**	**No**	**Total**	**Yes**	**No**	**Total**	**P value**
Lip Lick	8 (50)	8 (50)	16	14 (87.5)	2 (12.5)	16	**0.031**
Yawn	15 (93.7)	1 (6.3)	16	15 (93.7)	1 (6.3)	16	1.000
Paw raise	15 (93.7)	1 (6.3)	16	16 (100)	0	16	1.000
Head turn	12 (75)	4 (25)	16	14 (87.5)	2 (12.5)	16	0.625
Backing away	16 (100)	0 (0)	16	16 (100)	0	16	-
Show teeth	16 (100)	0 (0)	16	16 (100)	0	16	-

Appendix 8.5 The perceived meaning of the lip lick behaviour (open-ended questions)

Lip Lick survey 1 - Control (n = 20)	
Description	**n**
Emotion/feeling	
Anxiety/Anxious	9
Stress(ed)	7
Scared/Fearful	6
Nervous	3
Worried	2
Uncomfortable	1
Leave alone/do not come closer/ stop	4
Preparing to/occurs before an attack/bite	2
Due to increased or decreased salivation	2
Bottom of Ladder of Aggression	1
Preparing to fight/flight	1
They (dog) are not a threat	1

Lip Lick survey 2 - Control (n = 20)	
Description	**n**
Emotion/feeling	
Anxiety/Anxious	9
Stress(ed)	3
Scared/Fearful	3
Uncomfortable, discomfort	2
Nervous	1
Worried	1
Submissive	1
Threatened	1
Due to increased or decreased salivation	2
Preparing to/occurs before an attack/bite	1
Bottom of Ladder of Aggression	1
Preparing to fight/flight	1
They (dog) are not a threat, avoid confrontation	1
Hungry	1
A warning that they can bite/have teeth	1

Lip Lick Survey 1 – Exp. (n = 16)	
Description	**n**
Emotion/feeling	
Anxiety/Anxious	4
Scared/Fearful	3
Stress	2
Nervous	2
Uncomfortable	2
Uneasy, unsure, on edge	2
Confusion	1
Defensive	1
Warning signs of aggression/defensive	1
Hungry	1
Leave alone, do not come closer, stop	1
Ready to attack/bite	1

Lip Lick Survey 2 – Exp. (n =16)	
Description	**n**
Emotion/feeling	
Anxiety/Anxious	8
Scared/Fearful	3
Stress	2
Nervous	3
Worried	1
Aggressive/anger	1
Trying to get the approach to stop	1

Appendix 8.6 The perceived meaning of the yawn behaviour (open-ended question)

Yawn - Survey 1 Control (n = 20)	
Description	**n**
Emotion/feeling	
Stressed	10
Anxious	9
Scared/fearful	2
Relaxed	1
Tired	1
Discomfort	3
Comfortable	2
It is not a threat	1
Fight or flight response	1
Showing weakness	1

Yawn - Survey 2 Control (n = 20)	
Description	**n**
Emotion/feeling	
Stressed	7
Anxious	9
Scared/fearful	3
Relaxed	1
Nervous	1
Tired / sleepy	1
Feels threatened	1
Worried	2
Discomfort/Uncomfortable	1
Try to warn human off / Does not want to be approached	2
A sign of aggression	1
Submission	1
Calm itself / self soothe	1
Fight or flight response	1
I don't know	2

Yawn - Survey 1 Exp. (n = 16)	
Description	**n**
Emotion/feeling	
Anxious	4
Stressed	3
Relaxed	2
Tired	2
Nervous	1
Confused	1
Warning	2
Unease	2
Showing teeth	2
Ladder of aggression	1
Sign of appeasement	1
I don't know	3

Yawn - Survey 2 Exp. (n = 16)	
Description	**n**
Emotion/feeling	
Anxious	5
Stressed	3
Scared/fearful	3
Nervous	3
Unsure	2
Anger	1
Warning to back away	2
High behavioural arousal	1
Patience is running out	1
I don't know	1

Appendix 8.7 The perceived meaning of the paw raise behaviour (open-ended question)

Paw raise - Survey 1 Control (n = 20)	
Description	**n**
Emotion/feeling	
Anxious	3
Uncertain	4
Scared/fearful	4
Nervous	1
Uncomfortable	1
Preparing to move / back away	8
Preparing to warn/lunge /attack	2
Vulnerable	1
Moving up the Ladder of Aggression	1
Lip lick not working, so trying other signs	1
Submissive	1
I don't know	4

Paw raise - Survey 2 Control (n = 20)	
Description	**n**
Emotion/feeling	
Anxious	5
Uncertain / Uneasy	6
Scared/fearful	3
Nervous	2
Relaxed	1
Feels threatened	2
Preparing to move / back away	6
Trying to hide his fear	1
Vulnerable	1
Submissive	2
I don't know	2

Paw raise - Survey 1 Exp. (n = 16)	
Description	**n**
Emotion/feeling	
Anxious/agitated	2
Uncertain/uneasy	3
Scared/fearful	3
Nervous	1
Feeling trapped	1
Fight or flight	3
Preparing to move / back away	1
Confrontational / Trying to show power	2
Concentrating	1
Anticipating a stressor	1
I don't know	1

Paw raise - Survey 2 Exp. (n = 16)	
Description	**n**
Emotion/feeling	
Anxious	3
Uncertain/uneasy	3
Scared/fearful	2
Uncomfortable	2
Angry	1
Nervous	1
Stressed	1
Submissive	4
Preparing to move / back away	3
Vulnerable	2
Appeasement to get the person to stop / back off / dog wants its space	2
Alert and watching	1
I don't know	1

Appendix 8.8 Mean and median Igroup presence ratings for the control and intervention groups.

	Control (Survey 1)		Control (Survey 2)			Intervention (Survey 1)		Intervention (Survey 2)		
	Mean	Median	Mean	Median	p-value	Mean	Median	Mean	Median	p-value
General Presence	4	4	3.55	4	0.171	4.06	4	3.81	4	0.271
Spatial Presence	3.19	3	3.25	3	0.948	2.99	3	3.11	3	0.439
Involvement	2.88	3	2.91	3	0.737	2.84	3	2.73	2	0.671
Experienced Realism	2.71	3	2.79	3	0.602	2.59	3	2.67	3	0.648

CHAPTER 9. GENERAL DISCUSSION AND CONCLUSION

9.1 Introduction

This thesis contributes new evidence for the use of novel methods, using VR and online videos of the virtual model, in order to assess human-dog interactions. More specifically this thesis aimed to answer the question, 'Can DAVE (Dog-Assisted Virtual Environment) be used in the assessment of human behaviour towards dogs?'. Therefore, the aim of this study was to explore human behaviour in the presence of a virtual dog displaying non-reactive and aggressive behaviour. A range of objective measures were collected through VR and online videos including the proximity to the dog (i.e. the closest distance to the virtual dog), location of the user and corresponding dog behaviour (i.e. level of aggression), speed of approach, and total distance travelled. In addition, a range of subjective measures were also gathered including perceptions and interpretation of dog behaviour, perceived blame, presence, simulator sickness experienced and personality. The model was also used as an assessment tool pre- and post- an educational intervention (lecture and handling session) with first year veterinary students.

The result of this work is presented in the previous chapters. The aim of this chapter is to highlight the original contribution this work provides to the field human-animal interactions including the discussion of the dog model, its scope and to evaluate key findings from the research conducted. Finally, the limitations associated with this work, future research and conclusion are provided.

9.1.1 Dog Assisted Virtual Environment (DAVE)

The DAVE dog model is beneficial for the controlled assessment of human proximity and interactions around a dog, especially as the size and coat colour of the dog can be altered. Furthermore, the environment can be changed to an indoor living room or outdoor park. Therefore, this model overcomes the need for multiple live animals and environments and is likely to be valuable in helping to understanding human-dog interactions. DAVE may also be used as a tool in dog phobia treatment and in the education of dog behaviour and bite prevention for multiple audiences (e.g. public, students and professionals). Finally, the VR equipment used was of a high specification and allowed for real-world walking, referred to as the 'gold standard' for immersion, likely to be most similar to real-world movement compared to other forms of VR movement (teleportation, via a joystick) (Vasser and Aru, 2020).

As reviewed in Chapter 2, previous virtual dog models used in VR and AR have been developed; however, it was concluded that virtual dog behaviours varied between studies, were not supported by evidence, the choice of breed was biased, and the quality of dog models varied. Therefore, this research appears to be the first virtual dog model which utilises a widely accepted Canine Ladder of Aggression (CLA) model. The virtual dog model behaviour changes based on the location of the user and speed of approach and ranges from appeasement signals to behaviours indicating a direct threat. Furthermore, the dog model development was also reviewed and updated based on canine behaviour expert feedback. To avoid a biased opinion based on dog breeds, a Labrador was chosen which is often regarded as a family dog and a popular breed in the UK (Kennel Club, 2022; Kennel Club, no date).

However, given the specific context of this research a range of considerations should be noted. Firstly, this research specifically focusses on human approach behaviour towards a dog situated within a confined space displaying defensive aggression. Therefore, in its current form, this model only relates to defensive aggression. It is important to note that there are multiple types of aggression which may result in an aggressive response towards humans and/or animals (see Heath and Bowen, 2005; Haug, 2008).

Secondly, despite the dog model being based on the behaviours and the order, subject to speed of approach, as stated in the CLA, the behaviours listed in the CLA do not necessarily occur in a linear pattern (Meints *et al*., 2018; Owczarczak-Garstecka *et al*., 2018). Although behaviours were included based on the CLA, there were some behaviours from the CLA which were not included in the virtual dog model (such as lying down on their back) (Shepherd, 2009; Hedges, 2014). Additionally, some appeasement behaviours, such as curving, or softening of the eyes, are not covered in the CLA and therefore were not integrated into the model (Rugaas, 2006; Mariti *et al*., 2017). Currently, the dog model does not consider the variation which may be seen in real life due to individual differences (e.g. personality, breed), experience, context, or learnt behaviours in dogs (Bowen and Heath, 2005; Hedges, 2014; Meints *et al*., 2018). Having said this, the CLA is used in research (Meints *et al*., 2018), by professionals (Hedges, 2014) and all CLA behaviours were reviewed by behavioural experts and therefore the deemed sufficient as an initial starting point. The development of the dog behaviours mainly focused on the aggressive dog and less discussion and expert input was placed on the development of the non-reactive dog. For example, the non-reactive model simply repeats behaviours (see chapter 3) and does not make eye contact with the user unlike the aggressive dog model. Future development would be useful to incorporate more realistic dog behaviour into the non-reactive model.

Thirdly, human behaviour assessment in the presence of a live aggressive dog in real-time is problematic for both humans and dogs involved, as it would be unethical and a risk to human health and safety. Therefore, the use of a virtual dog model enables the safe interaction with a virtual dog without safety and welfare concerns for either dogs or humans. However, participant behaviour has only been tested in VR and not in real life and therefore it is unknown, and difficult to assess, if human behaviour transfers from VR to a real-world scenario. Previous research has found that safety skills, such as fire safety, learnt in VR can be transferred to the real world and aspects such as presence play a key role (Çakiroğlu and Gökoğlu, 2019). It is also worth noting that both VR tasks in the present research reported high levels of presence.

The ecological validity of the dog model may be boosted with the use of AR, a form of mixed reality, which allows a user to view both virtual objects whilst also viewing the real world. Previous research has explored human-dog interactions, such as dog walking, using AR (Norouzi *et al*., 2019), which requires less development time and cost than VR (Vinci *et al*., 2020) (also see future research section (9.8)). However, the ecological validity of the dog model's behaviour would still need to be explored. A benefit of VR, rather than AR, is that the virtual environment can be controlled, and changed which is likely to be of benefit when conducting research or training related to specific scenarios. For example, most dog bites have been reported to occur within the owner's own property, although dog bites in public are not uncommon (Reisner *et al*., 2011; Oxley *et al*., 2018), so replicating a home setting may have value and enable control over the environmental factors during research.

9.2 Can DAVE (Dog-Assisted Virtual Environment) be used in the assessment of human behaviour towards dogs?

9.2.1 Is there a difference between the safest proximity between the aggressive and the non-reactive dog model?

The first VR study (chapter 4) conducted involved participants being asked to 'explore the area' in the virtual environment for five minutes in the presence of an aggressive and non-reactive dog. Participants head and hand coordinates were automatically tracked through the use of the VR headset and base stations. Participants moved significantly closer to the non-reactive dog compared to the aggressive dog, suggesting that the dog model may be used in the assessment of human proximity in the presence of a virtual dog. The median distance of participants towards the non-reactive dog was 0.2 and 0.3m from the dog in two groups. This was regardless of the whether the aggressive dog was displayed first or last.

In the aggressive scenario, most participants (12/16) reached the level of aggression where the dog displayed more obvious signs of aggression (levels 7 and 8, i.e. growling and showing teeth). This could reflect a participant's ability to interpret behaviour signals displayed resulting in a person stopping only when they deem a behaviour to be potentially dangerous or threatening. This is despite half of the participants reporting seeing the lip lick and head turn behaviour. This also indicates that although participants may see appeasement behaviours they either choose to ignore or misinterpret the behaviour. This finding was consistent with previous research through other formats (video, animations) indicating that adult and/or children miss more subtle signs but can recognise more obvious signals such as large body movements, growling or showing teeth (Kerswell, 2009; Mariti *et al*., 2012; Meints *et al*., 2018)

It could be argued that as the instruction was given to 'explore the area' by an authoritative figure (i.e. the instructor), this could have been interpreted by the participants that the dog is safe to approach. Either way, consideration needs to be given regarding the instructions provided so as to not influence participant behaviour in future work especially as three people were 'bitten' by the virtual dog. This also places importance of conducting dog bite prevention education alongside practical sessions to ensure appropriate human behaviour around dogs in the real world. Having said this, in chapter 5 different instructions (e.g. place both handsets down on the floor and let go if or when you are at the closest distance you feel comfortable to the dog) were given to participants which resulted in similar findings to chapter 4. For example, in chapter 4 the median closest distance the participants head got to the aggressive dog was 0.9m and 1.1m compared to 1.0m and 1.3m in chapter 5 and two people were 'bitten' in Chapter 5. Like chapter 4, in chapter 5 participants mainly stopped at levels 6, 7 and 8.

9.3 What demographic or virtual model related factors impact human behaviour when viewing an aggressive virtual dog model?

9.3.1 Is a virtual dog performing aggressive behaviours perceived as realistic?

Perceived realism in a virtual environment is defined by an individual's view about the degree of realism regarding the "*virtual objects, sounds and scenes*" and "*the naturalness and ease of interaction*" (Weber *et al*., 2021). In the present study high specification equipment allowed real-world walking in the virtual environment. Participants also attempted to interact with the non-reactive dog and talk to the dog. This indicated a high degree of the perceived realism of the dog model and its behaviour. Participants appeared to be comfortable with the virtual environment and movement as simulator sickness scores were low, and the presence score indicated participants were immersed in the virtual environment. However, although the users attempted to interact with the dog model in VR, there was no haptic feedback when participant attempted to stroke or touch the dog. The only haptics were present when the aggressive dog lunged and bit (aggression level 9) at the users. This is an area that would benefit from further development and may increase the perceived realism of the dog model even further. Despite this, in chapter 5, the vast majority (>80%) agreed that the appearance, behaviour and vocalisations of the virtual dog in VR was like that of a real dog. Similarly, the majority of participants (>80%) in the international online survey also agreed that the dog's appearance, behaviour and vocalisations were like that of a real dog.

Given that most respondents in the present studies were dog owners it is positive to note the high level of perceived realism. It highlights the importance of the collaboration between canine behavioural and virtual reality experts. It also highlights the importance of using accepted behaviour models, such as the CLA. Previous published research (see chapter 2) using virtual dog models often only focus on the breed and appearance of the model and do not incorporate canine behaviour research into model behaviours and therefore behaviours are likely to be unrealistic.

Despite the results indicating that perceived realism was high the question was brief and broad (e.g. the behaviour/appearance/vocalisations of the virtual dog was like that of a real dog). Further development could explore the perceived realism in more detail which may, for example, include specific realism of individual behaviours or aspects of the dog's appearance. Furthermore, prior experience of VR may influence the view of perceived realism (Weber *et al*., 2021). For example, individuals who have never used VR or have only used low specification VR equipment may have had lower expectations and therefore perceive virtual content when using high specification equipment as more realistic.

9.3.2 Does coat colour of the dog affect how people behave towards it?

Coat colour is one of the characteristics that can be altered in the DAVE application, which is an especially contentious topic (e.g. black dog syndrome). Chapter 2 highlights the use of large black dogs in previous VR dog phobia research. Chapter 5 explored the role of coat colour on participants' willingness to approach a dog with a yellow or black coat. Regarding the total distance travelled and closest distance to the dog, there was no evidence of a difference between the two coat colours. However, dog ownership did appear to affect how close an individual got to the black dog, with those who had not owned a dog moving closer to the black dog than those who own(ed) dogs. In Chapter 7, there was no evidence of a difference in approach-stop times between dogs with a yellow and a black coat. As most respondents were currently and/or previously dog owners (91.2%) it is possible that previous ownership of a breed and/or dog with a specific coat colour influenced participant approach-stop behaviour. Future work could gather information about the breeds respondents have previously owned.

9.3.3 Does sound affect how people behave towards the aggressive dog?

The online survey (Chapter 6) found that there was no difference in approach behaviours between the aggressive dog without sound and with sound. However, there was evidence of a difference between the non-reactive dogs (sound and no sound).

9.3.4 Size of the dog

Expanding on the UK survey to further explore confounding variables of the DAVE dog model and environment, an international survey was conducted, which explored how close participants got to dogs of different sizes (small, medium, large), coat colours (yellow, black) and the environment (indoor, outdoor) (Chapter 6). Participants moved significantly closer to the 'small' dog than the 'large' or 'medium' dog. As previously discussed paedomorphic characteristics could have played a role as a 'cute effect'. It could be argued that participants were less able to interpret dog behaviour signals displayed by the small dog.

9.3.5 Indoor versus an outdoor environment

In Chapter 6, here was no significant difference between how close participants got towards the dogs in the indoor versus outdoor videos.

9.3.6 Gender

In Chapters 6 and 7, male participants stopped closer to the dog than females, which is supported by past research highlighting the increased risk of dog bites affecting males (Sacks *et al*., 1996; Westgarth *et al*., 2018), however, generally males are more likely to be injured than females (Udry, 1998). It is worth noting that both of these findings were found in two online, convenience samples, which tend to attract a larger proportion of female participants. As no gender difference was observed in the VR studies, which also suffered from unbalanced participant groups (i.e. more females), this topic requires further exploration with a more representative sample.

9.3.7 Dog experience

In Chapter 4, dog ownership was an influential factor when measuring the closest distance to the black aggressive dog, which could be influenced by broader factors (e.g. experience and perception). In Chapter 6, an online survey including a larger sample, again those who had not previously owned a dog also moved closer to a dog showing aggressive behaviours. Participants who had previously taken part in dog safety training stayed further away from the dog compared to individuals with no dog safety training. This indicates that the training received has influenced the distance participants are willing to get to the dog. Further exploration into the content and type of training. However, participants who had been previously bitten were also more likely to undertake training.

9.3.8 Human personality

A strong positive correlation between the conscientiousness score and distance from the yellow dog model when displaying aggressive behaviour (Chapter 5). However, the sample size was small and only consisted of a specific age group. In contrast, a large-scale survey consisting of 559 respondents (chapter 6) found a weak positive correlation between the distance of approach and the personality trait extraversion (i.e. more extraverted participants appeared to get closer to the dog) in the aggressive condition, with and without sound, and in the non-reactive condition, without sound.

The item used to assess respondents' personality in the present work was the Ten Item Personality Inventory (TIPI) to measure the Big-Five personality traits (Gosling *et al*., 2003). This tool consists of two questions per five individual traits (e.g. conscientiousness). The use of the TIPI in the present research was due to its previously validation, short length and therefore sufficient for a survey and, as stated by Gosling *et al*. (2003), the primary focus of the studies where the main aim of the study is not the assessment of participant personality. Furthermore, it has been used to explore participant personality in prior studies specifically relating to dog bite incidents (Westgarth *et al*., 2018). However, it should be noted that more comprehensive Big-Five personality measurement tools are available that may provide a more detailed insight than the TIPI. However, even the self assessment method of personality questionnaires has been critiqued (e.g. response bias) (McDonald, 2008). Some authors also have stated that self reporting method through surveys should be combined with a direct assessment method, such as through behaviour observations, are needed to more objectively assess personality (Kagan, 2007). Furthermore, the Big-Five personality model, although popular, is not a comprehensive review of personality nor is it the only model available (e.g. HEXACO, psychobiological model) and specific traits not covered by the Big-Five are also available (e.g. emotional intelligence) (Feher and Vernon, 2021). Given that a range of research has been recently conducted exploring the role of owner personality in human-animal interaction research which have identified that this is a complex area and may encompass multiple areas, which may play a role such as attachment level to an owner (e.g. Payne *et al*., 2015) and interaction style (e.g. Cimarelli *et al*., 2016). Therefore, future work needs to consider the latter aspects to help further understand the complex interaction between humans and familiar and unfamiliar dogs.

9.4 What behaviours and emotions do participants observe when viewing a virtual dog model displaying aggressive behaviour?

In Chapter 4, participants generally interpreted the aggressive dog's behaviour as indicating some form of negative emotional state, and all participants heard some form of vocalisation, indicating a broadly accurate interpretation of the dog's body language and vocalisations. In the VR tasks, results (Chapters 4 and 5) indicate that participants often were influenced by more obvious dog behaviours perceived to be aggressive (growling, showing teeth, barking), compared to more subtle behaviours (lip licking and yawning) which were associated with other forms of behaviour (e.g. play) and not necessarily a response to a threat.

Chapters 6 and 7, were somewhat consistent with chapter 4 and 5 whereby the majority of participants observed all behaviours. However, videos were watched after an approach-stop session and therefore participants may have already had an opportunity to see the behaviours. Furthermore, the automatic approach speed was slow and therefore this may have given participant more time to see and identify specific behaviours compared to the VR sessions.

9.5 Can a video of the virtual dog model be used to assess the perceived safest proximity to an aggressive dog and the interpretation of dog behaviour?

This thesis concludes that the DAVE model can be used to assess human proximity in the presence of a virtual dog in both VR and using videos taken from the virtual environment. It was found to be safe, realistic, and immersive, with no evidence of simulator sickness when viewed using the virtual headset, and humans responded as may be expected to the virtual dog models' behaviour, as if it was a real dog. However, there appeared to be differences in how close participants moved towards the dog in VR compared to the survey videos. For example, participants moved to level 7 or 8 in the VR. In contrast, over half of the participants in both online surveys only went as far as level 1. Multiple factors could have influenced this. The VR task allowed participants to move freely at their own speed. In contrast, the survey video displays a slow and continuous approach towards the dog model, and the participant could only press stop once per individual video.

There were consistencies between VR and online surveys as it was clear that most participants blamed either themselves or the dog's owner and infrequently blamed the dog for the dog’s response to their approach. This finding is consistent with previous research (Westgarth and Watkins., 2015; Oxley *et al*., 2019). This is surprising given that participants had no prior relationship with this dog, in fact, they knew it was not real, and had no additional details about the management or broader contexts (e.g. ownership, past behaviour, training, with the dog) and voluntarily moved towards it.

9.6 Can DAVE be used in the assessment of learning about dog behaviour and dog safety in veterinary students?

Finally, Chapter 8 was the first time the dog model was used as an intervention to assess the knowledge of first-year veterinary students pre- and post- a teaching and practical handling session. A voluntary online survey included approach-stop videos towards the aggressive virtual dog model. It was found that students did not get as close to the dog in the intervention group compared to the control group, and there was an increase in confidence in both the control and intervention groups. Given the current virtual environments, the development of a virtual veterinary consultation room would be helpful for context-specific research involving veterinary students. However, this study uses the current DAVE model as an intervention tool. Further exploration is needed to assess the use of DAVE in teaching and practical sessions in comparison or conjunction with more traditional methods for learning about canine behaviour and safe handling.

9.7 Limitations

For two VR studies participants were recruited through the University of Liverpool and were all students including undergraduate and/or post graduate students. However, this meant participants were between 18 – 35 years of age. Furthermore, across all studies (VR and online survey) there was a bias in female participants. Although not uncommon for online surveys relating to pet animals (e.g. Wijker *et al*., 2019; Wongsaengchan and Mckeegan, 2019), more control (e.g. set limits on number or proportion of males/females recruited) could avoid this from occurring in future work. This is especially important given that males are more commonly reported to be bitten than females (Fritschi *et al*., 2006; Tulloch *et al*., 2021; Westgarth *et al*., 2018).

Of the two VR studies conducted, 16 and 18 participants took part respectively. The first VR pilot study was intentionally cut short due to COVID restrictions resulting in 16 participants taking part compared to the 21 participants planned. Regarding the second VR study, the rate of attrition was higher than expected due to individuals either not responding to the invitation to the practical sessions or simply not turning up on the day. In future, incentives could be put in place to encourage participation and a large number of individuals could be recruited to take into account high attrition rates.

In the VR studies, participants were given verbal instructions about the virtual reality set up (e.g. virtual safety barrier) and the equipment just before the start of the VR tasks. However, there was no chance for participants to familiarise themselves with the virtual environment or use of the equipment and be immersed in the environment. Therefore, this could lead to participants experiencing a 'novelty effect' as when participants first use the VR equipment in the virtual environment they may focus more on the use of equipment (e.g. virtual hands) and viewing the virtual environment (Miguel-Alonso *et al*., 2024). Indeed, in the present research, although participants were randomised, there was also evidence of an order effect in VR (Chapter 4). A simple way to overcome this limitation is to allow a pre-training phase which may include the environment but without the dog present as this gives users the ability to test the equipment and become accustomed to the movement, immersion and the virtual environment (Miguel-Alonso *et al*., 2024).

In both VR and online videos, the environment included an empty room with a dog either displaying non-reactive or unresponsive behaviour. Given that educational advice often states that before approaching a dog a person should ask the owner if they can stroke or interact with the dog (Blue Cross, no date; American Kennel Club, 2023). However, in the videos the approach was automatic and the instructions in the VR were to explore the area for example. A simple way to overcome this limitation is to either inform the participant that they have been given permission to approach the dog and/or add a virtual avatar (i.e. the owner) within the virtual environment. However, further research is needed to explore the effect of human behaviour with and without a virtual 'owner' present. This is also important for messaging as it could be misinterpreted that participants can approach dogs that are on their own. It also emphasises the importance of a post educational session for users.

The non-reactive dog displayed several behaviours but was not responsive to the human approach or interaction. Further development of non-reactive dog model behaviour in this scenario would be useful to represent a relaxed or friendly dog model. For example, the dog could approach the user initially or move around the environment. It should also be noted that in Chapters 4 and 5, the non-reactive and aggressive scenario tasks were conducted in quick succession. Participants could have deemed the model to be the same dog but displaying different behaviours in quick succession.

Although participants were randomised, there was also evidence of an order effect in some cases (Chapter 4). This could be because the first VR task is more engaging (i.e. novelty effect), especially if participants have never used VR. A potential method to overcome any initial impacts on participants' response to the first use of VR and the virtual environment is to have an environment without the dog's presence as a first task. This also allows a participant to become accustomed to wearing the headset, and the virtual environment, whilst learning how to move and use the handsets.

The studies involving VR (Chapters 4 and 5) used a high-specification laptop to ensure portability, the power to run the VR application and support a high-end headset (HTC Vive Pro). Despite this, the VR headset remained tethered by a long HDMI cable to the headset. At the time of the initial development, high-specification headsets were tethered and required a high-powered laptop to run. In the current VR studies, the author controlled the location of the tethered cable to ensure it did not interfere with participants. However, there were some instances where participants made contact with the cable, such as when the participant turned around 360 degrees. Over recent years an increasing trend of commercial VR headsets is towards those that are standalone (untethered) as limited set-up is required, all the software is built into the headset, and no additional hardware is required (e.g. pc and base stations) and therefore is cost-effective as no pc/laptop is needed (Nyamtiga *et al*., 2022; Kari and Kosa, 2023). Untethered headsets do rely on battery packs and require built-in processing capabilities.

Pet dog owners are likely to be also overrepresented in the survey samples e.g. UK survey (56.9%); International survey (78.3%); as only 31% of UK households own a dog (UK Pet Food, 2023). Dog owners could also be more knowledgeable about dog behaviour than non-dog owners. Furthermore, as the surveys were distributed online, only participants who use and have access to the internet and social media or use it more frequently were able to take part.

Participants were specifically asked to use a PC to take part in the online surveys. However, it is likely that participant screens varied in size and quality, which could have affected the viewing of the videos and recognition of specific behaviours. Furthermore, videos have obvious limitations, such as the lack of control whereby participants can only press stop during video tasks.

9.8 Future research

9.8.1 Research using virtual reality

The VR set-up allowed for a real-world approach in terms of locomotion, regarded as the 'gold standard' in VR. However, this could be problematic due to the space required. All practical VR tasks were conducted in university lecture rooms as the space required was 6x2m for the virtual 'play area' alone. An even larger space was required for the additional equipment (base stations and laptop) placed outside this area and somewhere for the participant to complete the paper-based survey. Therefore, an area of at least 8x4m is preferable. Therefore, such a large space requirement may limit its use in specific scenarios, such as community events or educational or medical settings. To overcome this limitation, previous research has compared different methods of locomotion in VR, such as teleportation, walking on the spot, or via controller or joystick movement, which allows for the increased use of space in a virtual environment compared to the room-scale movement (Boletsis and Cerdegren, 2019). However, each method has benefits and disadvantages; for example, Boletsis and Cedergren (2019) compared locomotion methods in VR and concluded that although teleportation was a method that was easy for participants to use, it also resulted in a break in presence during teleportation. Similarly, they also found that movement, such as walking on the spot, results in user discomfort and fatigue. This area requires further research, especially in identifying if movement format affects proxemics with the virtual dog model, presence and simulator sickness. Furthermore, the head and hand tracking methods and their accuracy are important when exploring proxemics (i.e. measuring interactions with a dog and the closest distance to the dog). The current tracking of the headset (HTC Vive Pro) was outside-in and required the use of base stations. Alongside wireless headsets, there have been, and continue to be, advancements in VR technology, with multiple headsets using inside-out tracking being released in the last several years, for example, the Oculus Rift 2, released in 2022, is wireless, has inside-out tracking and does not require a computer to run. The need for base stations and tethered cables will likely become redundant in commercially available headsets in the near future, which may benefit future researchers or applied settings where space is a problem.

The effect of different methods of user locomotion in VR, equipment (headset quality and tracking (inside out/outside in)), and the potential effect these have on user experience and behaviour towards the DAVE dog model is yet to be tested in a research setting.

9.8.2 Future use of augmented reality

As discussed in Chapter 2, previous research has used a virtual dog in AR to explore proxemics when walking a virtual pet dog (Norouzi *et al*., 2019). Augmented Reality is an area that requires further research to understand its utility for measuring human-dog interactions as it can combine both the real environment and a virtual dog model, which may have some benefits. Comparisons between AR and VR would be useful especially in terms of attention participants pay to the dog in AR as the environment could stay the same as real-life, but the presence of the dog is the only change to the environment compared to VR where the virtual environment and dog model are both a novelty. Augmented reality could therefore be transferred to different settings such as a veterinary practice or a home setting, but this lack of standardised environment may also be a challenge in research design.

It is important to note that both AR and VR HMDs have ongoing technological challenges associated with them e.g. VR: display resolution; AR: limited horizontal field of vision (i.e. 60°), display brightness/luminance and the surrounding environment (Zhan *et al*., 2020). Finally, AR HMDs are less frequently available commercially compared to VR HMDs, all of which may impact the development and use in research at this time.

VR requires a virtual body / hands where AR does not as a user can view their own body which is also likely to affect the degree of realism experienced (Yapan *et al*., 2023). However, previous research has found that VR is beneficial especially in public speaking phobia treatment as this provided a feeling of security, and thus more people undertook phobia treatment in comparison to real life exposure (Garcia-Palacios *et al*., 2007). Further research would be useful using the dog model for phobia treatment and also to ascertain if mode of delivery affects patient uptake of phobia treatment when using either a real dog, AR, VR or online videos.

9.8.3 Eye tracking in virtual reality

Over recent years eyes tracking has been integrated into VR headsets and is commercially available (e.g. HTC Vive pro eye). This is a potentially useful area to help understand interactions between humans and dogs, i.e. objective measures of what dog body parts and behaviours attract participant attention and which may be overlooked when observing a dog, leading to possible dangerous or unsafe interactions. Previous eye or gaze-tracking studies involving human perceptions of dog emotional signals, mainly focus on facial expressions, using a screen displaying static images of dogs (Guo *et al.*, 2019; Correia-Caeiro *et al*., 2023). However, eye tracking is a complex area which requires a range of considerations, such as eye tracking method, data quality (i.e. sampling rate, accuracy, latency), calibration, and safety (e.g. long-term use of infra-red eye tracking may be problematic) (Adhanom *et al*., 2023).

Although presence ratings generally indicated sufficient level of immersion, the method of assessing presence was subjective through predefined validated questionnaires. Although the surveys used in the present study have been widely used in VR previous research has critiqued the use of this method and proposes researchers move away from surveys to assess presence (Slater *et al*., 2004). Whereas Grassini and Laumann (2020) suggests that multiple measures (physiological, behavioural, surveys) should be used together to measure the presence in VE. Furthermore, it has previously been noted that the transition from VR to a real-world environment (referred to as 'break in presence') to complete questionnaires is currently required and this can lead to side effects (e.g. disorientation (Knibbe *et al*., 2018) and biases (Putze *et al*., 2020)). Therefore, incorporating online surveys within the virtual environment has been previously used by handsets which act as pointers to answer questions (Putze *et al*., 2020) and has been found to reduce study time and the likelihood of disorientation (Schwind *et al*., 2019). However, the latter may be problematic for long questionnaires or questions which require open-ended answers, as seen within the present study or where multiple tasks are required. It may also be difficult to reposition the user at the starting point without the removal of the headset, although additional instructions could guide the user back to the starting location before the next task.

9.8.4 Dog model development

The dog model was seen as realistic by participants and confirmed both in terms of the presence questionnaires and the behaviour towards the dog. Regarding the aggressive dog model, the current model simply displays defensive aggression towards an unfamiliar person approaching it. Future iterations of development may want to assess individual knowledge about safety around dogs in more detail. For example, not approaching a dog when it is eating, or not waking a sleeping dog are contexts commonly reported in dog bite research and used in dog bite prevention advice and education (Dogs Trust, 2023; Blue Cross, 2023). Different forms of aggression (e.g. resource guarding) could also be explored, and the development of appropriate tasks (e.g. picking up the dog's bowl) to test participant understanding and knowledge of inappropriate or risky behaviour.

Regarding the non-reactive model, when respondents interacted with the dog, there was no haptic feedback, and the hand moved through the dog. This in itself could have reduced the realism. For example, when an individual interacts with a virtual dog and feels the appropriate haptic feedback, it may reduce the likelihood of the user moving their hand further through the dog model. A potential way to overcome this is to have a real-life object resembling a dog that people can physically touch to replace the virtual model. However, the movement of the dog would be problematic. Further exploration is needed on the role of haptics and interaction with the dog model (see Chapter 2 for a review of the development of haptic technology).

Currently, there were two markers on the dog model at the tip of the nose and the back of the head. It may be useful to increase the number of markers, e.g. to cover the length and width of the muzzle and head. Furthermore, automatic recording of when and for how long a person comes into 'contact' with the dog would be useful.

The most frequent question that is asked about the dog model is the availability of other dog breeds. Firstly, it is essential to highlight that the Labrador was chosen due to the view that it is a family dog, one of the most popular pedigree breeds in the UK and has three coat colours (yellow, black and liver/chocolate) (Kennel Club, n.d.). Having said this, there is clearly scope to explore a broad range of additional characteristics, such as skull shape/cephalic index, muzzle length, ear shape, coat and tail length which have been noted effect human interpretation of dog body language (Hecht and Horowitz, 2015; Bradshaw and Rooney, 2017; Schatz *et al*., 2021).

There are three environments which can be used with the dog model in the current set which include an indoor, outdoor and blank environment. Further development could be made to explore other scenarios in that dog bites frequently occur. Additional scenarios could also be developed for specific audiences such as a veterinary consultation room for veterinary student assessment and teaching or a kennel for kennel workers.

Although not studied within this thesis, the DAVE model may be helpful in teaching children, parents, and adults about recognising aggressive behaviours preceding a bite. In the present VR study, only students were included, and a broader range of participants is needed to inform future development. Furthermore, one aspect which is missing from the current application is a virtual human, which could be used as the 'owner' of the dog or simply a bystander. Educational programs and literature often state that owners or caregivers of a dog should be asked before approaching and stroking a dog (Dogs Trust, n.d.). Therefore, an optional virtual human/avatar in the virtual environments would allow educational tests in the presence of both an owner and without an owner.

An alternative use of the dog model would be in phobia treatment. Regarding dog phobia research, a number of papers use a dog which displays aggressive behaviours. This is likely to be inappropriate, at least initially, and the use of a dog displaying a range of friendly behaviours may be beneficial as a starting point. The current non-reactive dog does not react towards an approaching user, which could also be helpful for dog phobia research, but is less realistic.

9.9 Conclusion

It is dangerous and unethical to set up a research scenario with a live dog displaying defensive aggression towards humans; therefore, comparing the DAVE to a real-world comparable study is impossible. Given that this model has been developed and this is the first time it has been formally used in research, it highlights the potential for future development in helping understand human-dog interactions. It could help in dog bite prevention education, particularly for people with no prior dog ownership experience. The DAVE model has the advantage of allowing repeated, standardised trials that do not impact animal welfare. In addition, the model can be easily manipulated to control a range of variables hypothesised to impact human behaviour around dogs.

In the present study, participants differed in their stopping distance between non-reactive and aggressive, perceiving the dog model to be realistic in appearance and behaviour. Dog behaviours could be easily and readily assessed by participants. Notably, the VR equipment was easy to use by participants, and there were no reported side effects as a result of the research involving VR or online videos.

The results from this study are a novel method in helping further to understand human behaviour in the presence of aggressive dogs. Further model development and more research using VR and AR would be beneficial to support safety awareness and education initiatives relating to human-dog interactions.

REFERENCES

Adhanom, I. B., MacNeilage, P. and Folmer, E. (2023). Eye tracking in virtual reality: a broad review of applications and challenges. *Virtual Reality*, 27, 1481–1505.

Aguiar, N. R. and Taylor, M. (2015). Children's concepts of the social affordances of a virtual dog and a stuffed dog. *Cognitive Development*, 34, 16-27.

Ahn, S. J., Johnsen, K., Moore, J., Brown, S., Biersmith, M. and Ball, C. (2016). Using virtual pets to increase fruit and vegetable consumption in children: A technology-assisted social cognitive theory approach. *Cyberpsychology, Behavior, and Social Networking*, 19, 86-92.

Ahn, S. J., Johnsen, K., Robertson, T., Moore, J., Brown, S., Marable, A. and Basu, A. (2015). Using virtual pets to promote physical activity in children: An application of the youth physical activity promotion model. *Journal of Health Communication*, 20, 807-815.

Ainsworth, M. D. S. (1978). The bowlby-ainsworth attachment theory. *Behavioral and Brain Sciences*, 1, 436-438.

Alberghina, D., Virga, A., Sottile, G., Buffa, S.P. and Panzera, M. (2023). A 10-year retrospective analysis (2012-2021) of hospitalizations resulting from dog bites in Southern Italy. *Frontiers in veterinary science*, *10*, 1104477.

Albuquerque, N., Guo, K., Wilkinson, A., Savalli, C., Otta, E. and Mills, D. (2016). Dogs recognize dog and human emotions. *Biology Letters*, *12*, p.20150883.

Albuquerque, N., Mills, D. S., Guo, K., Wilkinson, A., and Resende, B. (2022). Dogs can infer implicit information from human emotional expressions. *Animal Cognition*, 25, 231-240.

Aldridge, G. L. and Rose, S. E. (2019). Young children's interpretation of dogs' emotions and their intentions to approach happy, angry, and frightened dogs. *Anthrozoös*, 32, 361-374.

American Kennel Club (2023). How to safely greet a dog you don't know. [www document] < https://www.akc.org/expert-advice/advice/how-to-safely-greet-a-strange-dog/ > (Accessed 04/02/2024).

Amici, F., Waterman, J., Kellermann, C. M., Karimullah, K. and Bräuer, J. (2019). The ability to recognize dog emotions depends on the cultural milieu in which we grow up. *Scientific Reports*, 9, 1-9.

Anderson, K. H., Yao, Y., Perry, P. J., Albright, J. D. and Houpt, K. A. (2022). Case distribution, sources, and breeds of dogs presenting to a veterinary behavior clinic in the United States from 1997 to 2017. *Animals*, 12, 576.

Andrews, C., Southworth, M. K., Silva, J. N. A. and Silva, J. R. (2019). Extended reality in medical practice. *Current Treatments Options in Cardiovascular Medicine*. 21, 18.

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N. and Evershed, J. K. (2020). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods*, 52, 388-407.

Anyfantakis, D., Botzakis, E., Mplevrakis, E., Symvoulakis, E. K. and Arbiros, I. (2009). Selective mutism due to a dog bite trauma in a 4-year-old girl: a case report. *Journal of Medical Case Reports*, 3, 1-3.

Arhant, C., Landenberger, R., Beetz, A. and Troxler, J. (2016). Attitudes of caregivers to supervision of child–family dog interactions in children up to 6 years—An exploratory study. *Journal of Veterinary Behavior*, 14, 10-16.

Arluke, A., Cleary, D., Patronek, G. and Bradley, J. (2018). Defaming rover: error-based latent rhetoric in the medical literature on dog bites. *Journal of Applied Animal Welfare Science*, 21, 211-223.

Armas J. and Andaluz V. H. (2018). Alternative treatment of psychological disorders such as spider phobia through virtual reality environments. In: Bebis G. et al. (eds) *Advances in Visual Computing. ISVC 2018. Lecture Notes in Computer Science*, 11241. Springer, Cham.

Atienza, R., Blonna, R., Saludares, M. I., Casimiro, J. and Fuentes, V. (2016 May). Interaction techniques using head gaze for virtual reality. In *2016 IEEE Region 10 Symposium (TENSYMP)* (pp. 110-114). IEEE.

Bailenson, J. N. (2018). Experience on demand: What virtual reality is, how it works and what it can do. W. W. Nortoon & Company. New York.

Bailenson, J. N. and Yee, N. (2006). A longitudinal study of task performance, head movements, subjective report, simulator sickness, and transformed social interaction in collaborative virtual environments. *PRESENCE: Teleoperators and Virtual Environments*, 15, 699-716.

Bain, M. (2009). Aggression toward unfamiliar people and animals. In Horwitz, D. and Mills, D. (eds.) BSAVA manual of canine and feline behavioural medicine (p. 211-222). BSAVA Library, UK.

Bálint, A., Rieger, G., Miklósi, A. and Pongrácz, P. (2017). Assessment of owner-directed aggressive behavioural tendencies of dogs in situations of possession and manipulation. *Royal Society Open Science*. 4, 171040.

Bamberger, M. and Houpt, K. A. (2006). Signalment factors, comorbidity, and trends in behavior diagnoses in dogs: 1,644 cases (1991–2001). *Journal of the American Veterinary Medical Association*, 229, 1591-1601.

Bartneck, C., Kulić, D., Croft, E. and Zoghbi, S. (2009). Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International Journal of Social Robotics*, 1, 71-81.

Basdogan, C., Ho, C. H., Srinivasan, M. A. and Slater, M. (2000). An experimental study on the role of touch in shared virtual environments. *ACM Transactions on Computer-Human Interaction*, 7, 443-460.

Baslington-Davies, A., Howell, H., Hogue, T. E. and Mills, D. S. (2023). An assessment of scientific evidence relating to the effect of early experience on the risk of human-directed aggression by adult dogs. *Animals*, 13, 2329.

Beck, A. M. and Jones, B. A. (1985). Unreported dog bites in children. *Public Health Reports*, 100, 315.

Beck, A. M., and Katcher, A. H. (2003). Future directions in human-animal bond research. *American Behavioral Scientist*, *47*, 79-93.

Beck, L. and Madresh, E. A. (2008). Romantic partners and four-legged friends: An extension of attachment theory to relationships with pets. *Anthrozoös*, 21, 43-56.

Beck, A. M. (2014). The biology of the human–animal bond. *Animal Frontiers*, 4, 32-36.

Bellows, J., Colitz, C. M., Daristotle, L., Ingram, D. K., Lepine, A., Marks, S. L., Sanderson, S. L., Tomlinson, J. and Zhang, J. (2015). Common physical and functional changes associated with aging in dogs. *Journal of the American Veterinary Medical Association*, 246, 67-75.

Bender, Y., Bräuer, J. and Schweinberger, S. R. (2023). What makes a good dog-owner team?–A systematic review about compatibility in personality and attachment. *Applied Animal Behaviour Science*, 105857.

Benz-Schwarzburg, J., Monsó, S. and Huber, L. (2020). How dogs perceive humans and how humans should treat their pet dogs: Linking cognition with ethics. *Frontiers in Psychology*, 11, 3587.

Berument, S. K., Rutter, M., Lord, C., Pickles, A. and Bailey, A. (1999). Autism screening questionnaire: Diagnostic validity. *British Journal of Psychiatry,* 175, 444–451.

Blecker, D., Hiebert, N. and Kuhne, F. (2013). Preliminary study of the impact of different dog features on humans in public. *Journal of Veterinary Behavior*, 8, 170-174.
Bloom, T. and Friedman, H. (2013). Classifying dogs'(*Canis familiaris*) facial expressions from photographs. *Behavioural Processes*, 96, 1-10.
Blue Cross (2023). Keeping your family dog and children safe. [www document] < https://www.bluecross.org.uk/advice/dog/keeping-your-family-dog-and-visiting-children-safe > (Accessed 01/08/2023).
Blue Cross (No date). How to approach a dog. [www document] < https://www.bluecross.org.uk/advice/dog/how-to-approach-a-dog > (Accessed 08/02/2024).
Boat, B. W., Dixon, C. A., Pearl, E., Thieken, L. and Bucher, S. E. (2012). Pediatric dog bite victims: a need for a continuum of care. *Clinical Pediatrics*, 51, 473-477.
Boletsis, C. (2017). The new era of virtual reality locomotion: a systematic literature review of techniques and a proposed typology. *Multimodal Technologies and Interaction*. 1, 24
Boletsis, C. and Cedergren, J. E. (2019). VR locomotion in the new era of virtual reality: an empirical comparison of prevalent techniques. *Advances in Human-Computer Interaction*, 2019. https://doi.org/10.1155/2019/7420781
Bolter, J. D., Engberg, M. and MacIntyre, B. (2021). Degrees of freedom: spatial tracking and sensing. In *Reality media: augmented and virtual reality* (p. 61 – 70). MIT Press.
Borchelt, P. L. (1983). Aggressive behavior of dogs kept as companion animals: classification and influence of sex, reproductive status and breed. *Applied Animal Ethology*, 10, 45-61.
Borgi, M., Cogliati-Dezza, I., Brelsford, V., Meints, K., and Cirulli, F. (2014). Baby schema in human and animal faces induces cuteness perception and gaze allocation in children. *Frontiers in psychology*, *5*, 411.
Botella, C., Bretón-López, J., Quero, S., Baños, R. and García-Palacios, A. (2010). Treating cockroach phobia with augmented reality. *Behavior Therapy*. 41, 401-413.
Bowen, J. and Heath, S. (2005). Canine Aggression problems. In *Behaviour problems in small animals: practical advice for the veterinary team* (p. 117 – 136). Elsevier Health Sciences, UK.
Bowlby, J. (1969). *Attachment and loss: Vol. 1. Attachment.* New York: Basic Books.
Bowlby, J. (1973). *Attachment and loss: Vol. 2. Separation, anxiety, and anger*. New York: Basic Books.
Boyd, C., Jarvis, S., McGreevy, P. D., Heath, S., Church, D. B., Brodbelt, D. C. and O'Neill, D. G. (2018). Mortality resulting from undesirable behaviours in dogs aged under three years attending primary-care veterinary practices in England. *Animal Welfare*, 27, 251-262.
Bradshaw, J. W., Blackwell, E. J. and Casey, R. A. (2009). Dominance in domestic dogs—useful construct or bad habit?. *Journal of Veterinary Behavior*, 4, 135-144.
Bradshaw, J. and Rooney, N. (2017). Dog social behavior and communication. In Serpell, J. (eds.) *The domestic dog: Its evolution, behavior and interactions with people*, pp.133-159. Cambridge University Press, UK
Brey, P. (2008). Virtual reality and computer simulation. In: Himma, K. E. and Tavani, H. T. (eds) *The handbook of information and computer ethics*. Wiley & Sons, London, UK.
Briones, E. M., and Marshall, P. H. (2022). The perception and effect of aggressive dog breeds on human social interactions. *Human-Animal Interaction Bulletin*, 13, 91-110.
Briones, E. M., Marshall, P. H., and Mangano, S. (2022). Perceived aggressive tendencies of, and functional attitudes towards, selected breeds of dogs. *Society &Animals*, (published online 2022). https://doi.org/10.1163/15685306-bja10073

Broom, D. M. and Fraser, A. F. (2015). Domestic animal behaviour and welfare. CAB International, Wallingford, UK.
Brown, W. P., Davidson, J. P. and Zuefle, M. E. (2013). Effects of phenotypic characteristics on the length of stay of dogs at two no kill animal shelters. *Journal of Applied Animal Welfare Science*, 16, 2-18.
Burt, G. (2016). Values, world society and modelling yearbook 2014. Cambridge Scholars Publishing, Cambridge, UK.
Butcher, R. and De Keuster, T. (2010). Dog bite injuries a preventable hazard?. *Injury Prevention*, 16(Suppl 1), A221-A221.
BVA (British Veterinary Association) (2015). Voice of the veterinary profession survey (prepared by Alpha Research). BVA, UK.
BVA (British Veterinary Association) (2022). Becoming a vet. [www document] https://www.bva.co.uk/your-career/becoming-a-vet/ (Accessed 22/02/2023).
Bylieva, D., Almazova, N., Lobatyuk, V. and Rubtsova, A. (2020). Virtual Pet: Trends of Development. In: Antipova, T. and Rocha, Á. (eds) *Digital Science 2019. DSIC 2019. Advances in Intelligent Systems and Computing*, vol 1114. Springer, Cham.
Byrne, S., Gay, G., Pollack, J. P., Gonzales, A., Retelny, D., Lee, T. and Wansink, B. (2012). Caring for mobile phone-based virtual pets can influence youth eating behaviors. *Journal of Children and Media*, 6, 83-99.
Caffrey, N., Mounchili, A., McConkey, S. and Cockram, M. S. (2011). Survey of euthanasia practices in animal shelters in Canada. *Canadian Veterinary Journal*, 52, 55-61.
Çakiroğlu, Ü. and Gökoğlu, S. (2019). Development of fire safety behavioral skills via virtual reality. *Computers & Education*, 133, 56-68.
Calder, C. D., Albright, J. D., and Koch, C. (2017). Evaluating graduating veterinary’students' perception of preparedness in clinical veterinary behavior for “Day-1” of practice and the factors which influence that perception: A questionnaire-based survey. *Journal of Veterinary Behavior*, 20, 116-120.
Camps, T., Amat, M. and Manteca, X. (2019). A review of medical conditions and behavioral problems in dogs and cats. *Animals*, 9, 1133.
Carlin, A. S., Hoffman, H. G. and Weghorst, S. (1997). Virtual reality and tactile augmentation in the treatment of spider phobia: A case report. *Behaviour Research and Therapy*, 35, 153-158.
Casey, R. A., Loftus, B., Bolster, C., Richards, G. J., and Blackwell, E. J. (2013). Inter-dog aggression in a UK owner survey: prevalence, co-occurrence in different contexts and risk factors. *Veterinary Record*, 172, 127.
Casey, R. A., Loftus, B., Bolster, C., Richards, G. J., and Blackwell, E. J. (2014). Human directed aggression in domestic dogs (*Canis familiaris*): Occurrence in different contexts and risk factors. *Applied Animal Behaviour Science*, 152, 52-63.
Chapman, S., Cornwall, J., Righetti, J. and Sung, L. (2000). Preventing dog bites in children: randomised controlled trial of an educational intervention. *British Medical Journal*, 320, 1512-1513.
Chen, Z. H., Liao, C., Chien, T. C. and Chan, T. W. (2011). Animal companions: Fostering’children's effort-making by nurturing virtual pets. *British Journal of Educational Technology*, 42, 166-180.
Chesney, T. and Lawson, S. (2007). The illusion of love: Does a virtual pet provide the same companionship as a real one?. *Interaction Studies*, 8, 337-342.
Christley, R., Nelson, G., Millman, C. and Westgarth, C. (2021). Assessment of detection of potential dog-bite risks in the home using a real-time hazard perception test. *Anthrozoös*, 34, 767-786.

Cimarelli, G., Turcsán, B., Bánlaki, Z., Range, F. and Virányi, Z. (2016). Dog owners' interaction styles: Their components and associations with reactions of pet dogs to a social threat. *Frontiers in Psychology*, *7*, 1979.
Cohen, J. (1988*). Statistical power analysis for the behavioral sciences* (second edition). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.
Col, R., Day, C. and Phillips, C. J. (2016). An epidemiological analysis of dog behavior problems presented to an Australian behavior clinic, with associated risk factors. *Journal of Veterinary Behavior*, 15, 1-11.
Cook, J. A., Sasor, S. E., Soleimani, T., Chu, M. W., and Tholpady, S. S. (2020). An epidemiological analysis of pediatric dog bite injuries over a decade. *Journal of Surgical Research*, 246, 231-235.
Cornelissen, J. M. and Hopster, H. (2010). Dog bites in The Netherlands: a study of victims, injuries, circumstances and aggressors to support evaluation of breed specific legislation. *Veterinary Journal*, 186, 292-298.
Correia-Caeiro, C., Guo, K. and Mills, D. S. (2023). Visual perception of emotion cues in dogs: a critical review of methodologies. *Animal Cognition*, 26, 727–754.
Cruz-Neira, C., Sandin, D. J., DeFanti, T. A., Kenyon, R.V. and Hart, J. C. (1992). The CAVE: audio visual experience automatic virtual environment. *Communications of the ACM*, *35*, 64-73.
Cui, Y., Russell, M., Davern, M. and Christian, H. (2021). Longitudinal evidence of the impact of dog ownership and dog walking on mental health. *Journal of Public Health*, 43, e145-e152.
Cummings, J. J. and Bailenson, J. N. (2016). How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media psychology*, 19, 272-309.
Cutt, H., Giles-Corti, B., Knuiman, M., and Burke, V. (2007). Dog ownership, health and physical activity: A critical review of the literature. *Health & Place*, 13, 261-272.
D'Aniello, B., Scandurra, A., Alterisio, A., Valsecchi, P. and Prato-Previde, E. (2016). The importance of gestural communication: a study of human–dog communication using incongruent information. *Animal Cognition*, 19, 1231-1235.
Dahlman, J., Falkmer, T. and Forsman, F. (2012). Perceived motion sickness and effects on performance following naval transportation. *Journal of Human Performance in Extreme Environments*, 10, 3. doi: 10.7771/2327-2937.1046
Davis, A. L., Schwebel, D. C. Morrongiello, B. A. Stewart, J. and Bell, M. (2012) Dog bite risk: an assessment of child temperament and child-dog interactions. *International Journal Environmental Research and Public Health*, 9, 3002-3013. https://doi.org/10.3390/ijerph9083002
Davis, S., Nesbitt, K. and Nalivaiko, E. (2014). December. A systematic review of cybersickness. In *Proceedings of the 2014 Conference on Interactive Entertainment* (p. 1 - 9).
De Keuster, T., Lamoureux, J. and Kahn, A. (2006). Epidemiology of dog bites: a Belgian experience of canine behaviour and public health concerns. *Veterinary Journal*, *172*, 482-487.
de Vasconcelos, G., Malard, M. L., van Stralen, M., Campomori, M., Canavezzi de Abreu, S., Lobosco, T., Gomes, I. F. and Duarte Costa Lima, L. (2019). Do we still need CAVEs?. 37 Education and Research in Computer Aided Architectural Design in Europe and XXIII Iberoamerican Society of Digital Graphics, Joint Conference (N.1), Blucher Design Proceedings, 7, 133-141.
Delise, K. (2007). The Pit Bull Placebo: The media, myths and politics of canine aggression. Anubis publishing.

Demirbas, Y. S., Ozturk, H., Emre, B., Kockaya, M., Ozvardar, T. and Scott, A. (2016). Adults' ability to interpret canine body language during a dog–child interaction. *Anthrozoös*, 29, 581-596.
Denis-Robichaud, J., Aenishaenslin, C., Richard, L., Desmarchelier, M. and Carabin, H. (2022). Association between pet ownership and mental health and well-being of canadians assessed in a cross-sectional study during the COVID-19 Pandemic. *International Journal Environmental Research and Public Health*, 19, 2215.
Dennison, M. S. and Krum, D. M. (2019). Unifying Research to Address Motion Sickness, *IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, Osaka, Japan, 1858-1859.
Dennison, M. S., Wisti, A. Z. and D'Zmura, M. (2016). Use of physiological signals to predict cybersickness. *Displays*, 44, 42-52.
Dhillon, J., Hoopes, J. and Epp, T. (2019). Scoping decades of dog evidence: a scoping review of dog bite-related sequelae. *Canadian Journal of Public Health*, 110, 364-375.
Dibbets, P., Lemmens, A., Benning, R., & Smeets, T. (2021). Can you escape the virtual room? A novel paradigm to assess avoidance behaviour. *Computers in Human Behavior Reports*, *3*, 100061.
Diesel, G., Brodbelt, D., and Pfeiffer, D. U. (2010). Characteristics of relinquished dogs and their owners at 14 rehoming centers in the United Kingdom. *Journal of Applied Animal Welfare Science*, 13, 15-30.
Diesel, G., Pfeiffer, D. U., and Brodbelt, D. (2008). Factors affecting the success of rehoming dogs in the UK during 2005. *Preventive Veterinary Medicine*, 84, 228-241.
Dixon, C. A. and Mistry, R. D. (2020). Dog bites in children surge during coronavirus Disease-2019: a case for enhanced prevention. *Journal of Pediatrics*, 225, 231-232.
Dodman, N. H., Brown, D. C. and Serpell, J. A. (2018). Associations between owner personality and psychological status and the prevalence of canine behavior problems. *PloS one*, *13*, e0192846.
Dogs Trust. (2023). Dog and children: living together safely. [www document] < https://www.dogstrust.org.uk/help-advice/dog-care/staying-safe-around-dogs > (Accessed 02/08/2023)
Döring, D., Roscher, A., Scheipl, F., Küchenhoff, H. and Erhard, M. H. (2009). Fear-related behaviour of dogs in veterinary practice. *Veterinary Journal*. 182, 38-43.
Duffy, D. L., Hsu, Y. and Serpell, J. A. (2008). Breed differences in canine aggression. *Applied Animal Behaviour Science*, 114, 441-460.
Dużmańska, N., Strojny, P. and Strojny, A. (2018). Can simulator sickness be avoided? A review on temporal aspects of simulator sickness. *Frontiers in Psychology*, 9, 2132.
DVM360. (2020). Workplace safety. DVM360, May 2020, 51, 26.
Edens, M. A., Michel, J. A. and Jones, N. (2016). Mammalian bites in the emergency department: recommendations for wound closure, antibiotics, and postexposure prophylaxis. *Emergency Medicine Practice*, 18, 1-20.
Edney, A. T. (1995). Companion animals and human health: an overview. *Journal of the Royal Society of Medicine*, 88, 704-708.
EFRA (Environment, Food and Rural Affairs) Committee (2013). Dog control and welfare: Seventh report of session 2012-2013. House of Commons, The Stationary Office, London, UK.
Engdahl, K. S., Brodbelt, D. C., Cameron, C., Church, D. B., Hedhammar, Å., and O'Neill, D. G. (2023). Demography and disorders of English Cocker Spaniels under primary veterinary care in the UK. *Canine Medicine and Genetics*, 10, 4. https://doi.org/10.1186/s40575-023-00128-x

Engel, G. L. (1980). The clinical application of the biopsychosocial model. *American Journal of Psychiatry*, 137, 535-544.

Epp, T. and Waldner, C. (2012). Occupational health hazards in veterinary medicine: zoonoses and other biological hazards. *Canadian Veterinary Journal,* 53, 144.

Eretová, P., Chaloupková, H., Hefferová, M. and Jozífková, E. (2020). Can children of different ages recognize dog communication signals in different situations?. *International Journal of Environmental Research and Public Health*, 17, 506.

Evans-Wilday, A. S., Hall, S. S., Hogue, T. E. and Mills, D. S. (2018). Self-disclosure with dogs: Dog owners' and non-dog owners' willingness to disclose emotional topics. *Anthrozoös*, 31, 353-366.

Faragó, T., Takács, N., Miklósi, Á. and Pongrácz, P. (2017). Dog growls express various contextual and affective content for human listeners. *Royal Society Open Science*, *4*, 170134.

Farrell, L. J., Miyamoto, T., Donovan, C. L., Waters, A. M., Krisch, K. A. and Ollendick, T. H. (2021). Virtual reality one-session treatment of child-specific phobia of dogs: a controlled, multiple baseline case series. *Behavior Therapy*. 52, 478-491.

Fatjo, J., Amat, M., Mariotti, V. M., de la Torre, J. L. R., and Manteca, X. (2007). Analysis of 1040 cases of canine aggression in a referral practice in Spain. *Journal of Veterinary Behavior, 2*, 158-165.

Faul, F., Erdfelder, E., Lang, A.-G. and Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39, 175-191.

FEDIAF (European Pet Food Industry) (2021). Facts and Figures 2021. [www document] < https://www.dropbox.com/s/h3vapzfju5j8vei/Facts%20and%20Figures%202021.pdf?dl=0 > (Accessed on 23/05/2020).

Feher, A. and Vernon, P.A. (2021). Looking beyond the Big Five: A selective review of alternatives to the Big Five model of personality. *Personality and Individual Differences*, 169, 110002.

Ferretti, V. and Papaleo, F. (2019). Understanding others: Emotion recognition in humans and other animals. *Genes, Brain and Behavior*, 18, e12544. https://doi.org/10.1111/gbb.12544

Fine, A., and Mackintosh, T. (2016). Animal-assisted interventions: Entering a crossroads of explaining an instinctive bond under the scrutiny of scientific inquiry, p. 68-73. In Friedman, H. S. (ed.) *Encyclopedia of Mental Health*, Elsevier, USA.

Fine, A. H. and Weaver, S. J. (2018). The human-animal bond and animal-assisted intervention. *Oxford textbook of nature and public health: The role of nature in improving the health of a population*, 132-138.

Fine, A. H. and Ferrell, J. (2021). Conceptualizing the human–animal bond and animal-assisted interventions. In: Peralta, J.M., Fine, A.H. (eds.) *The welfare of animals in animal-assisted interventions*. Springer, Cham. p. 21–41.

Firnkes, A., Bartels, A., Bidoli, E. and Erhard, M. (2017). Appeasement signals used by dogs during dog–human communication. *Journal of Veterinary Behavior*, 19, 35-44.

Flint, H. E., Coe, J. B., Serpell, J. A., Pearl, D. L. and Niel, L. (2017). Risk factors associated with stranger-directed aggression in domestic dogs. *Applied Animal Behaviour Science*, 197, 45-54.

Forrester, M. B. (2020). Dog leash-related injuries treated at emergency departments. *American Journal of Emergency Medicine*. 38, 1782-1786.

Fox, J., Arena, D. and Bailenson, J. N. (2009). Virtual reality: A survival guide for the social scientist. *Journal of Media Psychology*, 21, 95-113.

Fragoso, S., Anjos, C., Almeida, A., Manteca, X. and de Sousa, L. (2022). Dog bites in Portugal: Analysis of incidents, and consequences for both people and dogs. *Journal of Veterinary Behavior*, 54, 19-27.

Fratkin, J. L. and Baker, S. C. (2013). The role of coat color and ear shape on the perception of personality in dogs. *Anthrozoös*, *26*, 125-133.

Friedman, E. and Krause-Parello, C. A. (2018). Companion animals and human health: benefits, challenges, and the road ahead for human-animal interaction. *Revue scientifique et technique (International Office of Epizootics)*, 37, 71-82.

Fritschi, L., Day, L., Shirangi, A., Robertson, I., Lucas, M. and Vizard, A. (2006). Injury in Australian veterinarians. *Occupational Medicine*, 56, 199-203.

Gazzano, A., Zilocchi, M., Massoni, E., and Mariti, C. (2013). Dogs' features strongly affect people's feelings and behavior toward them. *Journal of Veterinary Behavior*, 8, 213-220.

Garcia-Palacios, A., Botella, C., Hofman, H. and Fabregat, S. (2007). Comparing acceptance and refusal rates of virtual reality exposure vs. in vivo exposure by patients specific phobias. *Cyberpsychology and Behavior*, 10, 722–724.

Gee, N. R. and Mueller, M. K. (2019). A systematic review of research on pet ownership and animal interactions among older adults. *Anthrozoös*, 32, 183-207.

Gee, N. R., Rodriguez, K. E., Fine, A. H., and Trammell, J. P. (2021). Dogs supporting human health and well-being: A biopsychosocial approach. *Frontiers in Veterinary Science*, 8, 630465.

Gilchrist, J., Sacks, J. J., White, D. and Kresnow, M. J. (2008). Dog bites: still a problem?. *Injury Prevention*, 14, 296.

Gobbo, E. and Zupan, M. (2020). Dogs' sociability, owners' neuroticism and attachment style to pets as predictors of dog aggression. *Animals*, *10*, 315.

Gonçalves, G., Monteiro, P., Melo, M., Vasconcelos-Raposo, J. and Bessa, M. (2020). A comparative study between wired and wireless virtual reality setups. *IEEE Access*, 8, 29249-29258.

Goncalves, G., Monteiro, P., Coelho, H., Melo, M. and Bessa, M. (2021). Systematic review on realism research methodologies on immersive virtual, augmented and mixed realities. *IEEE Access*, *9*, 89150-89161.

Gosling, S. D., Rentfrow, P. J., and Swann, W. B., Jr. (2003). A very brief measure of the big five personality domains. *Journal of Research in Personality, 37, 504-528.*

Gourlay, M. J. and Held, R. T. (2017). Head-Mounted-Display tracking for augmented and virtual reality. *Information Display*, 33, 6-10.

Grassini, S. and Laumann, K. (2020). Questionnaire measures and physiological correlates of presence: A systematic review. *Frontiers in Psychology*, 11, 349.

Greenfield, S. (2013). How to reduce stress in the veterinary waiting room. *Veterinary Nurse*, 4, 494-501.

Guo, K., Li, Z., Yan, Y. and Li, W. (2019). Viewing heterospecific facial expressions: an eye-tracking study of human and monkey viewers. *Experimental Brain Research*, 237, 2045-2059.

Guy, N. C., Luescher, U. A., Dohoo, S. E., Spangler, E., Miller, J. B., Dohoo, I. R. and Bate, L. A. (2001). Demographic and aggressive characteristics of dogs in a general veterinary caseload. *Applied Animal Behaviour Science*. 74, 15-28.

Guy, N. C., Luescher, U. A., Dohoo, S. E., Spangler, E., Miller, J. B., Dohoo, I. R., and Bate, L. A. (2001). Risk factors for dog bites to owners in a general veterinary caseload. *Applied Animal Behaviour Science*, 74, 29-42.

Hahn, L., Rathbun, S. L., Schmidt, M. D., Johnsen, K., Annesi, J. J. and Ahn, S. J. G. (2020). Using virtual agents and activity monitors to autonomously track and assess self-

determined physical activity among young children: a 6-week feasibility field study. *Cyberpsychology Behaviour, and Social Networking*. *23*, 471-478.
Hall, S., Dolling, L., Bristow, K., Fuller, T. and Mills, D. S. (2017). *Companion animal economics: The economic impact of companion animals in the UK*. CAB International, Wallingford, UK.
Hampson, K., Coudeville, L., Lembo, T., Sambo, M., Kieffer, A., Attlan, M., Barrat, J., Blanton, J. D., Briggs, D. J., Cleaveland, S. and Costa, P. (2015). Estimating the global burden of endemic canine rabies. *PLOS Neglected Tropical Diseases*, 9, p.e0003709.
Harding, S. (2012). *Unleashed: The phenomena of status dogs and weapon dogs*. Policy Press, UK.
Hare, B., Wobber, V. and Wrangham, R. (2012). The self-domestication hypothesis: evolution of bonobo psychology is due to selection against aggression. *Animal Behaviour*, 83, 573-585.
Hart, B. L., Hart, L. A. and Bain, M. J. (2006). General approaches to behavioral pharmacology (p. 63 – 73). In *Canine and feline behavior therapy*. Blackwell Publishing, US.
Haug, L. I. (2008). Canine aggression toward unfamiliar people and dogs. *Veterinary Clinics of North America: Small Animal Practice*, 38, 1023-1041.
Hecht, J. and Horowitz, A. (2015). Introduction to dog behaviour (p. 5 – 30). In Weiss, E., Mohan-Gibbons, H. and Zawistowski, S. *Animal behavior for shelter veterinarians and staff*, John Wiley & Sons, US.
Hedges, S. (2014). *Practical Canine behaviour for veterinary nurses and technicians*. CAB International, Wallingford, UK.
Henery, P. M., Dundas, R., Katikireddi, S. V., Leyland, A., Wood, R. and Pearce, A. (2021). Social inequalities and hospital admission for unintentional injury in young children in Scotland: A nationwide linked cohort study. *The Lancet Regional Health-Europe*, 6, 100117.
Herbert, A., Wijlaars, L., Zylbersztejn, A., Cromwell, D. and Hardelid, P. (2017). Data resource profile: Hospital episode statistics admitted patient care (HES APC). *International Journal of Epidemiology*, 46, 1093-1093i.
Herbst, K. C., Gaertner, L. and Insko, C. A. (2003). My head says yes but my heart says no: Cognitive and affective attraction as a function of similarity to the ideal self. *Journal of Personality and Social Psychology*, 84, 1206-1219.
Herzog, H. (2021). Women dominate research on Human-Animal Bond. Am. Psychol. May 24. [www document] < https://www.psychologytoday.com/us/blog/animals-and-us/202105/women-dominate-research-thehuman-animal-bond > (Accessed 08/10/2021).
Hevern, M. E. (2022). Welfare worries: a preliminary, cross-sectional study of general practice, small animal veterinarians perceptions and management of canine and feline behaviour problems. *Australian Veterinary Journal*, 100, 377– 387.
Higuera-Trujillo, J. L., Maldonado, J. L. T. and Millán, C. L. (2017). Psychological and physiological human responses to simulated and real environments: A comparison between Photographs, 360 Panoramas, and Virtual Reality. *Applied Ergonomics*, 65, 398-409.
Hnoohom, N. and Nateeraitaiwa, S. (2017, March). Virtual reality-based smartphone application for animal exposure. In *2017 International Conference on Digital Arts, Media and Technology (ICDAMT)* (pp. 417-422). IEEE.
Hopwood, C. J., Stahlmann, A. G. and Bleidorn, W. (2023). Personality and compassion for animals. *Anthrozoös,* 36, 69-81.

Horisberger, U., Stärk, K. D. C., Rüfenacht, J., Pillonel, C. and Steiger, A. (2004). The epidemiology of dog bite injuries in Switzerland–characteristics of victims, biting dogs and circumstances. *Anthrozoös*, 17, 320-339.
Hughes, J. and Macdonald, D. W. (2013). A review of the interactions between free-roaming domestic dogs and wildlife. *Biological Conservation*, 157, 341-351.
Hung, Y. P., Huang, T. M., Li, K. T., Rajapakse, R. J., Chen, Y. S., Han, P. H., Liu, I.S., Wang, H. C. and Yi, D. C. (2018, October). Simulating the activity of archaeological excavation in the immersive virtual reality. *In 2018 3rd Digital Heritage International Congress (DigitalHERITAGE) held jointly wit[h] 2018 24th International Conference on Virtual Systems & Multimedia (VSMM 2018)* (pp. 1-4). IEEE.
Hurst, P. J., Hwang, M. J. H., Dodson, T. B. and Dillon, J. K. (2020). Children have an increased risk of periorbital dog bite injuries. *Journal of Oral and Maxillofacial Surgery*, 78, 91-100.
Jacobs, J. A., Pearl, D. L., Coe, J. B., Widowski, T. M. and Niel, L. (2017). Ability of owners to identify resource guarding behaviour in the domestic dog. *Applied Animal Behaviour Science*, 188, 77-83.
Jacobs, J. A., Coe, J. B., Pearl, D. L., Widowski, T. M. and Niel, L. (2018). Factors associated with canine resource guarding behaviour in the presence of people: A across-sectional survey of dog owners. *Preventive Veterinary Medicine*, 161, 143-153.
Jakeman, M., Oxley, J. A., Owczarczak-Garstecka, S. C. and Westgarth, C. (2020). Pet dog bites in children: management and prevention. *BMJ Paediatrics Open*, 4, e000726.
Jalongo, M. R. (2018). Keeping Children Safe: *Children's Ability to Interpret Canine Behavioral Cues and Dog Safety Interventions*. In: Jalongo, M. R. (eds) Children, Dogs and Education. Springer, Cham.
Jeyaretnam, J., Jones, H. and Phillips, M. (2000). Disease and injury among veterinarians. *Australian Veterinary Journal*, 78, 625-629.
Ji, L., Xiaowei, Z., Chuanlin, W. and Wei, L. (2010). Investigation of posttraumatic stress disorder in children after animal-induced injury in China. *Pediatrics*, 126, e320-e324.
Johnsen, K., Ahn, S. J., Moore, J., Brown, S., Robertson, T. P., Marable, A. and Basu, A. (2014). Mixed reality virtual pets to reduce childhood obesity. *IEEE Transactions in Visualization and Computer Graphics*, 20, 523-530.
Johnston, S. (2018). Virtual reality as new media. In: Lee N. (eds) *Encyclopedia of Computer Graphics and Games*. Springer, Cham. doi:10.1007/978-3-319-08234-9_87-1
Kagan, J. (2007). A trio of concerns. *Perspectives on Psychological Science*, 2, 361-376.
Kahn, A., Bauche, P., Lamoureux, J. and Dog Bites Research Team. (2003). Child victims of dog bites treated in emergency departments: a prospective survey. *European Journal of Pediatrics*, 162, 254-258.
Kaminski, J. and Nitzschner, M. (2013). Do dogs get the point? A review of dog–human communication ability. *Learning and Motivation*, 44, 294-302.
Kamphuis, C., Barsom, E., Schijven, M., and Christoph, N. (2014). Augmented reality in medical education?. *Perspectives on Medical Education*, 3, 300-311.
Kardong-Edgren, S. S., Farra, S. L., Alinier, G. and Young, H. M. (2019). A call to unify definitions of virtual reality. *Clinical Simulation in Nursing*, 31, 28-34.
Kari, T. and Kosa, M. (2023). Acceptance and use of virtual reality games: an extension of HMSAM. *Virtual Reality*. 27, 1585-1605
Kartashova, I. A., Ganina, K. K., Karelina, E. A. and Tarasov, S. A. (2021). How to evaluate and manage stress in dogs–A guide for veterinary specialist. *Applied Animal Behaviour Science*. 243, 105458. https://doi.org/10.1016/j.applanim.2021.105458

Keeling, L. and Jensen, P. (2017). Abnormal behaviour, stress and welfare. In Jensen, P. (eds) *The ethology of domestic animals–an introductory text* (third edition), 85-101. CAB International, Wallingford, UK.
Kennedy, R. S., Drexler, J. M., Compton, D. E., Stanney, K. M., Lanham, D. S. and Harm, D. L. (2003). Configural scoring of simulator sickness, cybersickness and space adaptation syndrome: similarities and differences. In *Virtual and Adaptive Environments: Applications, Implications, and Human Performance Issues*, CRC Press.
Kennedy, R. S., Lane, N. E., Berbaum, K. S. and Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The International Journal of Aviation Psychology*, 3, 203-220.
Kennel Club (2020)' Britain's top dogs revealed: Labradors lead, Corgis come back and Jack Russells jump. [www document] < https://www.thekennelclub.org.uk/media-centre/2020/february/britains-top-dogs-revealed-labradors-lead-corgis-come-back-and-jack-russells-jump/ > (Accessed: 07/12/2021).
Kennel Club (2022). Breeds a to z. https://www.thekennelclub.org.uk/search/breeds-a-to-z/ (Accessed 16/04/2022).
Kennel Club (No date) Breed registration statistics -10 year breed statistics. [www document] < https://www.thekennelclub.org.uk/media-centre/breed-registration-statistics/ > (Accessed 27/07/2023).
Kennel Club (No date). Top twenty breeds in registration order for the year 2018 and 2019. https://www.thekennelclub.org.uk/media/1160770/2018-2019-top-20.pdf (Accessed: 21/04/2020).
Kerswell, K. J., Bennett, P. J., Butler, K. L. and Hemsworth, P. H. (2009). Self-reported comprehension ratings of dog behavior by puppy owners. *Anthrozoös*, 22, 183-193.
Kikuchi, M. and Oxley, J. A. (2017). The representation of human directed aggression in the popular media. In: Westgarth, C. and Mills, D. (Eds*) Dog Bites: A Multidisciplinary Perspective*. 5M publishing, Sheffield, UK.
Kim, K., Bruder, G. and Welch, G. (2017, November). Exploring the effects of observed physicality conflicts on real-virtual human interaction in augmented reality. In *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology*, 1-7.
King, G.A., Law, M., King, S., Hurley, P., Hanna, S., Kertoy, M. and Rosenbaum, P. (2007). Measuring children's participation in recreation and leisure activities: construct validation of the CAPE and PAC. *Child: Care, Health and Development*, 33, 28-39.
Kis, A., Turcsán, B., Miklósi, Á. and Gácsi, M. (2012). The effect of the owner's personality on the behaviour of owner-dog dyads. *Interaction Studies*, 13, 373-385.
Klaassen, B., Buckley, J. R. and Esmail, A. (1996). Does the dangerous dogs act protect against animal attacks: a prospective study of mammalian bites in the accident and emergency department. *Injury*, 27, 89-91.
Knibbe, J., Schjerlund, J., Petraeus, M., and Hornbæk, K. (2018, April). The dream is collapsing: the experience of exiting VR. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (p. 1 - 13).
Knight, S. and Edwards, V. (2008). In the company of wolves: the physical, social, and psychological benefits of dog ownership. *Journal of Aging and Health*, 20, 437-455.
Kobelt, A. J., Hemsworth, P. H., Barnett, J. L., Coleman, G. J., and Butler, K. L. (2007). The behaviour of Labrador retrievers in suburban backyards: The relationships between the backyard environment and dog behaviour. *Applied Animal Behaviour Science*, 106, 70-84.

Kogan, L. R., Hellyer, P. W., Rishniw, M. and Schoenfeld-Tacher, R. (2020). Veterinary behavior: Assessment of veterinarians' training, experience, and comfort level with cases. Journal of Veterinary Medical Education, 47, 158-169.

Kogan, L. R., Schoenfeld-Tacher, R. M., Hellyer, P. W., Oxley, J. A. and Rishniw, M. (2019). Small Animal Veterinarians' Perceptions, Experiences, and Views of Common Dog Breeds, Dog Aggression, and Breed-Specific Laws in the United States. *International Journal of Environmental Research and Public Health*, 16, 4081. doi:10.3390/ijerph16214081

Kogan, L., Hellyer, P., Duncan, C. and Schoenfeld-Tacher, R. (2017). A pilot investigation of the physical and psychological benefits of playing Pokémon GO for dog owners. *Computers in Human Behavior*, 76, 431-437.

Kotrschal, K., Schöberl, I., Bauer, B., Thibeaut, A. M. and Wedl, M. (2009). Dyadic relationships and operational performance of male and female owners and their male dogs. *Behavioural Processes*, 81, 383-391.

Krahé, B. (2013). Defining and measuring aggression. In *The Social Psychology of Aggression*. Psychology Press Ltd, East Sussex, UK.

Kringelbach, M. L., Stark, E. A., Alexander, C., Bornstein, M. H. and Stein, A. (2016). On cuteness: Unlocking the parental brain and beyond. *Trends in cognitive sciences*, 20, 545-558.

Kubinyi, E., Turcsán, B. and Miklósi, Á. (2009). Dog and owner demographic characteristics and dog personality trait associations. *Behavioural Processes*, 81, 392-401.

Kuhne, F. (2016). Behavioural responses of dogs to dog-human social conflict situations. *Applied Animal Behaviour Science*, 182, 38-43.

Kurdek, L. A. (2009). Pet dogs as attachment figures for adult owners. *Journal of Family Psychology*, 23, 439.

Kurdek, L. A. (2009a). Young adults' attachment to pet dogs: findings from open-ended methods. *Anthrozoös*, 22, 359-369.

Labrodex Studios (2019). Original Content: Dex. [www document] < https://labrodex.com /original-content/ > (Accessed: 03/01/2021).

Lakestani, N. N., Donaldson, M. L. and Waran, N. (2014). Interpretation of dog behavior by children and young adults. *Anthrozoös*, 27, 65-80.

Lakestani, N. and Donaldson, M. L. (2015). Dog bite prevention: Effect of a short educational intervention for preschool children. *PLoS One*, 10, e0134319.

Lalley, J. P., Piotrowski, P. S., Battaglia, B., Brophy, K. and Chugh, K. (2010). A Comparison of V-Frog [C] to Physical Frog Dissection. *International Journal of Environmental and Science Education*, 5, 189-200.

Landercasper, J., Cogbill, T. H., Strutt, P. J. and Landercasper, B. O. (1988). Trauma and the veterinarian. *Journal of Trauma*, 28, 1255-1259.

Landsberg, G., Hunthausen, W. and Ackerman, L. (2013). *Behaviour problems of the dog and cat* (Third edition). Elsevier Ltd, USA.

Langley, R. L. (2012). Animal-related injuries resulting in emergency department visits and hospitalizations in the United States, 2006–2008. *Human-Wildlife Interactions*, 6, 123-136.

Lanier, J. (2017). Dawn of the new everything: Encounters with reality and virtual reality. Henry Holt and Company.

Laureano-Cruces, A. L. and Rodriguez-Garcia, A. (2012). Design and implementation of an educational virtual pet using the OCC theory. *Journal of Ambient Intelligence and Humanized Computing*, 3, 61-71.

LaViola Jr, J. J. (2000). A discussion of cybersickness in virtual environments. *ACM Sigchi Bulletin*, 32, 47-56.

Lee, J., Kim, M. and Kim, J. (2017). A study on immersion and VR sickness in walking interaction for immersive virtual reality applications. *Symmetry*, 9, 78.

Lee, M., Norouzi, N., Bruder, G., Wisniewski, P. J. and Welch, G. F. (2018 November). The physical-virtual table: exploring the effects of a virtual human's physical influence on social interaction. In *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology.* 1-11.

Lee, K. J., You, Y., Kim, Y. W., Lee, D. C., Koh, S. H., Kim, J. S., Roh, S. Y. and Hong, M. K. (2019). Domestic dog and cat bites: Epidemiology and analysis of 823 cases over the last 5 Years. *Journal of Wound Management and Research*, 15, 68-77.

Lemmens, A., Aarts, E. and Dibbets, P. (2024). Itsy bitsy spider: Fear and avoidance (generalization) in a free-exploratory virtual reality paradigm. *Behaviour Research and Therapy*, 172, 104442.

Lepper, M., Kass, P. H. and Hart, L. A. (2002). Prediction of adoption versus euthanasia among dogs and cats in a California animal shelter. *Journal of Applied Animal Welfare Science*, 5, 29-42.

Lilly, M. L., Arruda, A. G., Proudfoot, K. L. and Herron, M. E. (2020). Evaluation of companion animal behavior knowledge among first-year veterinary students before and after an introductory animal behavior course. Journal of the American Veterinary Medical Association, 256, 1153-1163.

Lin, C., Faas, T. and Brady, E. (2017, October). Exploring affection-oriented virtual pet game design strategies in VR attachment, motivations and expectations of users of pet games. In *2017 Seventh International Conference on Affective Computing and Intelligent Interaction (ACII)*(p. 362 - 369). IEEE.

Lindsay, S. R. (2000). *Handbook of applied dog behavior and training, volume 1, adaptation and learning*. Iowa State University Press.

Lindsay, S. R. (2001). Handbook of applied dog behavior and training. Vol. 2, Etiology and assessment of behavior problems. Iowa State University Press.

Llobera, J., Spanlang, B., Ruffini, G. and Slater, M. (2010). Proxemics with multiple dynamic characters in an immersive virtual environment. *ACM Transactions on Applied Perception (TAP)*, 8, 1-12.

Loder, R. T. (2019). The demographics of dog bites in the United States. *Heliyon*, *5*, e01360

Lofgren, S. E., Wiener, P., Blott, S. C., Sanchez-Molano, E., Woolliams, J. A., Clements, D. N., and Haskell, M. J. (2014). Management and personality in Labrador retriever dogs. *Applied Animal Behaviour Science*, 156, 44-53.

Lord, K., Feinstein, M., Smith, B. and Coppinger, R. (2013). Variation in reproductive traits of members of the genus Canis with special attention to the domestic dog (Canis familiaris). *Behavioural Processes*, 92, 131-142.

Love, M. and Overall, K. L. (2001). How anticipating relationships between dogs and children can help prevent disasters. *Journal of the American Veterinary Medical Association*, 219, 446-453.

Lowery, K. and Rosen, T. (2020). Dog walking can be hazardous to cutaneous health. *Cutis*. 105, 191-194.

Lucas, M., Day, L., Shirangi, A. and Fritschi, L. (2009). Significant injuries in Australian veterinarians and use of safety precautions. *Occupational Medicine*, 59, 327-333.

Luescher A. U. (2014). Canine behaviour and development. In Martin, D. and Shaw, J. (eds.) *Canine and Feline Behavior for Veterinary Technicians and Nurses*. Wiley, West Sussex, UK. p30-50

Luescher, A. U. and Reisner, I. R. (2008). Canine aggression toward familiar people: a new look at an old problem. *Veterinary Clinics of North America: Small Animal Practice*, 38, 1107-1130.

Luh, D. B., Li, E. C. and Kao, Y. J. (2015). The development of a companionship scale for artificial pets. *Interacting with Computers*, 27, 189-201.
Luo, H., Yang, T., Kwon, S., Zuo, M., Li, W. and Choi, I. (2020). Using virtual reality to identify and modify risky pedestrian behaviors amongst Chinese children. *Traffic Injury Prevention*, 21, 108-113.
Macpherson, C. N., Meslin, F. X. and Wandeler, A. I. (eds.) (2013). Dogs, Zoonoses and Public Health. CABI, UK.
Maglaya, P. G. V., Varlez, K. M. and Panergo, D. J. (2019). Virtual reality fear treatment. *International Journal of Recent Technology and Engineering*, 8, 139-140.
Manning, A. and Dawkins, M. S. (2012). An introduction to animal behaviour. Cambridge University Press.
Mannion, C. J. and Greenberg, D. (2016). Dog bites–are vets missing an educational opportunity?. *Veterinary Record*, 178, 535-536.
Mariti, C., Gazzano, A., Moore, J. L., Baragli, P., Chelli, L. and Sighieri, C. (2012). Perception of dogs' stress by their owners. *Journal of Veterinary Behaviour*, 7, 213-219.
Mariti, C., Falaschi, C., Zilocchi, M., Fatjó, J., Sighieri, C., Ogi, A., and Gazzano, A. (2017). Analysis of the intraspecific visual communication in the domestic dog (Canis familiaris): A pilot study on the case of calming signals. *Journal of Veterinary Behavior*, 18, 49-55.
Martens, P., Su, B. and Deblomme, S. (2019). The ecological paw print of companion dogs and cats. *BioScience*, 69, 467-474.
Maskey, M., Rodgers, J., Grahame, V., Glod, M., Honey, E., Kinnear, J., Labus, M., Milne, J., Minos, D., McConachie, H. and Parr, J. R. (2019). A randomised controlled feasibility trial of immersive virtual reality treatment with cognitive behaviour therapy for specific phobias in young people with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 49, 1912-1927.
Mathews, J. R. and Lattal, K. A. (1994). A behavioral analysis of dog bites to children. *Journal of Developmental and Behavioral Pediatrics*, 15, 44-52.
McDonald, J. D. (2008). Measuring personality constructs: The advantages and disadvantages of self-reports, informant reports and behavioural assessments. *Enquire*, 1, 1-19.
McNicholas, J. and Collis, G. M. (2000). Dogs as catalysts for social interactions: Robustness of the effect. *British Journal of Psychology*, 91, 61-70.
Meade, P. C. (2006). Police and domestic dog bite injuries: What are the differences? What are the implications about police dog use?. *Injury Extra*, *37*, 395-401.
Meehan, M., Massavelli, B. and Pachana, N. (2017). Using attachment theory and social support theory to examine and measure pets as sources of social support and attachment figures. *Anthrozoös*, 30, 273-289.
Meints, K., and De Keuster, T. (2009). Brief report: don't kiss a sleeping dog: the first assessment of "the blue dog" bite prevention program. *Journal of Pediatric Psychology*, 34, 1084-1090.
Meints, K., Racca, A. and Hickey, N. (2010). How to prevent dog bite injuries? Children misinterpret dogs facial expressions. *Injury Prevention.* 16, A68.
Meints, K. (2017). Children and dogs: Risks and effective dog bite prevention. In Mills, D.S. and Westgarth, C. (eds.) *Dog bites: A multidisciplinary perspective*. 5M Publishing, Sheffield, UK.
Meints, K., Brelsford, V. and De Keuster, T. (2018). Teaching children and parents to understand dog signalling. *Frontiers in Veterinary Science*, 5, 257.

Mendl, M., Burman, O. H. and Paul, E. S. (2010). An integrative and functional framework for the study of animal emotion and mood. *Proceedings of the Royal Society B: Biological Sciences*, 277, 2895-2904.

Menor-Campos, D .J., Williams, J. M., Gazzano, A. and Mariti, C. (2022). Student veterinarians' ability to recognize behavioral signs of stress in dogs. *Journal of Veterinary Behaviour*, 50, 46-52.

Messam, L. L. M., Kass, P. H., Chomel, B. B. and Hart, L. A. (2018). Factors associated with bites to a child from a dog living in the same home: A bi-national comparison. *Frontiers in Veterinary Science*, 5, 66.

Mestre, D. R. (2017). CAVE versus Head-Mounted Displays: Ongoing thoughts. *Electronic Imaging*, 3, 31-35.

Meyer, I., Forkman, B. and Paul, E. S. (2014). Factors affecting the human interpretation of dog behaviour. *Anthrozoös*, 27, 127-140.

Miguel-Alonso, I., Rodriguez-Garcia, B., Checa, D. and Bustillo, A. (2023). Countering the novelty effect: A tutorial for immersive virtual reality learning environments. *Applied Sciences*, 13, 593.

Milgram, P. and Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems*, 77, 1321-1329.

Mills, D. S. (2017). Dog bites and aggressive behaviour key underpinning principles for their scientific study. In Mills, D. S. and Westgarth, C. (eds.) *Dog bites: A multidisciplinary perspective.* 5m Publishing Ltd, Sheffield, UK.

Mills, D. S. and Zulch, H. (2010). Appreciating the role of fear and anxiety in aggressive behavior by dogs. *Veterinary Focus*, 20, 44-49.

Mills, D. S., Dube, M. B. and Zulch, H. (2013). Communication and information transfer. In *Stress and pheromonatherapy in small animal clinical behaviour* (p. 69-91). John Wiley & Sons, Oxford, UK.

Mills, D. S., van der Zee, E. and Zulch, H. (2014). When the bond goes wrong: problem behaviours in the social context. In *The Social Dog* (pp. 223-245). Academic Press, UK.

Miloff, A., Lindner, P., Dafgård, P., Deak, S., Garke, M., Hamilton, W., Heinsoo, J., Kristoffersson, G., Rafi, J., Sindemark, K. and Sjölund, J. (2019). Automated virtual reality exposure therapy for spider phobia vs. in-vivo one-session treatment: A randomized non-inferiority trial. *Behaviour Research and Therapy*, 118, 130-140.

Miloff, A., Lindner, P., Hamilton, W., Reuterskiöld, L., Andersson, G. and Carlbring, P. (2016). Single-session gamified virtual reality exposure therapy for spider phobia vs. traditional exposure therapy: study protocol for a randomized controlled non-inferiority trial. *Trials*, 17, 60.

Minns, S., Levihn-Coon, A., Carl, E., Smits, J. A., Miller, W., Howard, D., Papini, S., Quiroz, S., Lee-Furman, E., Telch, M. and Carlbring, P. (2018). Immersive 3D exposure-based treatment for spider fear: A randomized controlled trial. *Journal of Anxiety Disorders*, 58, 1-7.

Mishra, S. and Palkhade, R. (2020). Risk factors and prevalence of work-related injuries and accidents among veterinarians in India. *Veterinary World*, 13, 2555.

Moher, D., Liberati, A., Tetzlaff, J. and Altman, D. G. (2009). Methods of systematic reviews and meta-analysis preferred reporting items for systematic reviews and meta-analyses: the PRISMA Statement. *Journal of Clinical Epidemiology*, 62, 1006-12.

Monica, R. and Aleotti, J. (2022). Evaluation of the Oculus Rift S tracking system in room scale virtual reality. *Virtual Reality*, 1-11.

Montrose, V. T., Squibb, K., Hazel, S., Kogan, L. R. and Oxley, J. A. (2020). Dog bites dog: The use of news media articles to investigate dog-on-dog aggression. *Journal of Veterinary Behavior*, 40, 7-15.
Mora, E., Fonseca, G. M., Navarro, P., Castaño, A. and Lucena, J. (2018). Fatal dog attacks in Spain under a breed-specific legislation: A ten-year retrospective study. *Journal of Veterinary Behavior*, 25, 76-84.
Morel, M., Bideau, B., Lardy, J. and Kulpa, R. (2015). Advantages and limitations of virtual reality for balance assessment and rehabilitation. *Clinical Neurophysiology*, 45, 315-326.
Morgan, M. and Palmer, J. (2007). Dog bites. *British Medical Journal*, 334, 413-417.
Morrongiello, B. A., Schwebel, D. C., Stewart, J., Bell, M., Davis, A. L. and Corbett, M. R. (2013). Examining parents' behaviors and supervision of their children in the presence of an unfamiliar dog: Does The Blue Dog intervention improve parent practices?. *Accident Analysis & Prevention*, 54, 108-113.
Morrongiello, B. A., Corbett, M., Milanovic, M., Pyne, S. and Vierich, R. (2015). Innovations in using virtual reality to study how children cross streets in traffic: Evidence for evasive action skills. *Injury Prevention*, 21, 266-270.
Mountford, V. A., Tchanturia, K. and Valmaggia, L. (2016). "What are you thinking when you look at me?" A pilot study of the use of virtual reality in body image. *Cyberpsychology, Behavior, and Social Networking*, 19, 93-99.
Mousavi, M., Jen, Y. H. and Musa, S. N. B. (2013). A review on cybersickness and usability in virtual environments. *Advanced Engineering Forum*, 10, 34-39.
Mugford, R. (2007). Behavioural disorders in dogs. In Jensen (ed). *The behavioural biology of dogs*. p225-242. CAB international Wallingford, UK.
Munafo, J., Diedrick, M. and Stoffregen, T. A. (2017). The virtual reality head-mounted display Oculus Rift induces motion sickness and is sexist in its effects. *Experimental Brain Research*, 235, 889-901.
Nakamura R., Nunes F. L. S. and Tori, R. (2021). Enhanced Visualization by Augmented Reality. In: Lee N. (eds) *Encyclopedia of Computer Graphics and Games*. Springer, Cham. doi:10.1007/978-3-319-08234-9_83-1
Nakamura, M., Dhand, N., Wilson, B. J., Starling, M. J., and McGreevy, P. D. (2020). Picture perfect pups: How do attributes of photographs of dogs in online rescue profiles affect adoption speed?. *Animals*, 10, 152. https://doi.org/10.3390/ani10010152
Nesbitt, K., Davis, S., Blackmore, K. and Nalivaiko, E. (2017). Correlating reaction time and nausea measures with traditional measures of cybersickness. *Displays.* 48, 1–8.
Nettle, D. (2005). An evolutionary approach to the extraversion continuum. *Evolution and Human Behavior*, *26*, 363-373.
Netto, W. J. and Planta, D. J. (1997). Behavioural testing for aggression in the domestic dog. *Applied Animal Behaviour Science*, 52, 243-263.
Newman, J., Christley, R., Westgarth, C. and Morgan, K. (2017) Risk factors for dog bites – An epidemiological perspective. In mills, D. and Westgarth, C. (eds.) Dog Bites a multidisciplinary perspective. CABI publishing, UK.
NHS Digital (2009). Hospital episode statistics, admitted patient care – England, 2008-09. https://digital.nhs.uk/data-and-information/publications/statistical/hospital-admitted-patient-care-activity/hospital-episode-statistics-admitted-patient-care-england-2008-09 (Accessed 24/04/2020).
NHS Digital (2015). Provisional monthly topic of interest: admissions caused by dogs and other mammals. [www document] https://files.digital.nhs.uk/pdf/h/6/animal_bites _m12_1415.pdf (Accessed 03/04/2022).

NHS Digital (2019). Hospital admitted patient care activity 2019-2020. [www document] https://digital.nhs.uk/data-and-information/publications/statistical/hospital-admitted-patient-care-activity/2019-20 (Accessed 24/05/2022).
NHS Providers (2021). August 2021 Activity Tracker. [www document] https://nhsproviders.org/nhs-activity-tracker/august-2021 (Accessed 16/11/2021).
Nienhaus, A., Skudlik, C., Seidler, A. (2005). Work-related accidents and occupational diseases in veterinarians and their staff. *International Archives of Occupational and Environmental Health*, 78, 230-238.
Norouzi, N., Kim, K., Lee, M., Schubert, R., Erickson, A., Bailenson, J., Bruder, G. and Welch, G. (2019). Walking your virtual dog: Analysis of awareness and proxemics with simulated support animals in augmented reality. In 2019 IEEE International Symposium on Mixed and Augmented Reality (ISMAR) (pp. 57-168). IEEE.
Notari, L., Cannas, S., Di Sotto, Y. A. and Palestrini, C. (2020). A retrospective analysis of dog–dog and dog–human cases of aggression in northern Italy. *Animals*, 10, 1662.
Nyamtiga, B. W., Hermawan, A. A., Luckyarno, Y. F., Kim, T. W., Jung, D. Y., Kwak, J. S., and Yun, J. H. (2022). Edge-computing-assisted virtual reality computation offloading: an empirical study. *IEEE Access*, 10, 95892-95907.
O'Farrell, V. (1995). Effects of owner personality and attitudes on dog behaviour. In Serpell (ed.) *The Domesticated Dog its Evolution Behaviour and Interaction with People. Cambridge University Press, Cambridge, UK*, 151-158.
O'Haire, M. E., McKenzie, S. J., Beck, A. M., and Slaughter, V. (2015). Animals may act as social buffers: Skin conductance arousal in children with autism spectrum disorder in a social context. *Developmental Psychobiology*, 57, 584–595.
O'Sullivan, E. N., Jones,'B. R., O'Sullivan, K. and Hanlon, A. J. (2008). Characteristics of 234 dog bite incidents in Ireland during 2004 and 2005. *Veterinary Record*, 163, 37-42.
Oculus (No date). Legal documents. Health and safety. [www document] < https://www.oculus.com/legal/health-and-safety-warnings/?locale=en_GB > (accessed on 20/10/2020).
Oláh, K., Topál, J. and Gergely, A. (2021). Communication in Dogs and Wolves. In Kaufman, A., Call, J. and Kaufman, J. (Eds.), *The Cambridge Handbook of Animal Cognition* (Cambridge Handbooks in Psychology), 74-99. Cambridge: Cambridge University Press. doi:10.1017/9781108564113.006
Ollendick, T.H. (1983). Reliability and validity of the revised fear survey schedule for children (FSSC-R). *Behaviour Research and Therapy*, 21, 685-692.
Omaki, E., Rizzutti, N., Shields, W., Zhu, J., McDonald, E., Stevens, M. W. and Gielen, A., (2017). A systematic review of technology-based interventions for unintentional injury prevention education and behaviour change. *Injury Prevention*, 23, 138-146.
ONS (Office of National Statistics) (2020). United Kingdom population mid-year estimate. [www document] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/timeseries/ukpop/pop (Accessed 01/07/2020).
Orihel, J. S., Ledger, R. A. and Fraser, D. (2005). A survey of the management of inter-dog aggression by animal shelters in Canada. *Anthrozoös*, 18, 273-287.
Orritt, R. (2014). Dog ownership has unknown risks but known health benefits: we need evidence based policy. *British Medical Journal*, 349, g4081.
Overall, K. (2013). Manual of clinical behavioral medicine for dogs and cats e-book. Elsevier Health Sciences.

Overall, K. L., and Love, M. (2001). Dog bites to humans—demography, epidemiology, injury, and risk. *Journal of the American Veterinary Medical Association*, 218, 1923-1934.
Ovodov, N. D., Crockford, S. J., Kuzmin, Y. V., Higham, T. F., Hodgins, G. W. and van der Plicht, J. (2011). A 33,000-year-old incipient dog from the Altai Mountains of Siberia: evidence of the earliest domestication disrupted by the Last Glacial Maximum. *PloS one*, 6, e22821. https://doi.org/10.1371/journal.pone.0022821
Owczarczak-Garstecka, S. C., Watkins, F., Christley, R. and Westgarth, C. (2018). Online videos indicate human and dog behaviour preceding dog bites and the context in which bites occur. *Scientific Reports*, 8, 1-11.
Owczarczak-Garstecka, S. C., Watkins, F., Christley, R., Yang, H. and Westgarth, C. (2018a). Exploration of perceptions of dog bites among YouTube™ viewers and attributions of blame. *Anthrozoös*, 31, 537-549.
Oxley J. A., Meyer, G., Cant, I., Bellantuono, G. M., Butcher M, et al. (2022). A pilot study investigating human behaviour towards DAVE (Dog-Assisted Virtual Environment) and interpretation of non-reactive and aggressive behaviours during a virtual reality exploration task. PLOS One, 17 e0274329 https://doi.org/10.1371/journal.pone. 0274329
Oxley, J. A., Christley, R. and Westgarth, C. (2018). Contexts and consequences of dog bite incidents. *Journal of Veterinary Behavior*, *23*, 33-39.
Oxley, J. A., Christley, R., and Westgarth, C. (2019). What is a dog bite? Perceptions of UK dog bite victims. *Journal of Veterinary Behavior*, 29, 40-44.
Oxley, J. A., Santa, K., Meyer, G. and Westgarth, C. (2022). A Systematic Scoping Review of Human-Dog Interactions in Virtual and Augmented Reality: The Use of Virtual Dog Models and Immersive Equipment. *Frontiers in Virtual Reality*, 3.
Pallant, J. (2016). *SPSS survival manual*. Open University Press: Berkshire, UK
Pan, X., and Hamilton, A. F. D. C. (2018). Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape. *British Journal of Psychology*, 109, 395-417.
Park, J. W., Kim, D. K., Jung, J. Y., Lee, S. U., Chang, I., Kwak, Y. H., and Hwang, S. (2019). Dog-bite injuries in Korea and risk factors for significant dog-bite injuries: A 6-year cross-sectional study. *PloS One*, 14, e0210541.
Pasadyn, S. R., Soudan, M., Gillinov, M., Houghtaling, P., Phelan, D., Gillinov, N., Bittel, B. and Desai, M. Y. (2019). Accuracy of commercially available heart rate monitors in athletes: a prospective study. *Cardiovascular Diagnosis and Therapy*, 9, 379.
Paul, E. S., Packer, R. M., McGreevy, P. D., Coombe, E., Mendl, E. and Neville, V. (2023). That brachycephalic look: Infant-like facial appearance in short-muzzled dog breeds. *Animal Welfare*, 32, e5.
Payne, E., Bennett, P. C. and McGreevy, P. D. (2015). Current perspectives on attachment and bonding in the dog–human dyad. *Psychology Research and Behavior Management*, 8, 71-79.
PDSA (People's Dispensary for Sick Animals) (2022). PDSA Animal Wellbeing (PAW) Report 2022. [www document] < https://www.pdsa.org.uk/what-we-do/pdsa-animal-wellbeing-report/paw-report-2022 > (accessed 10/06/2023).
PDSA (People's Dispensary for Sick Animals) (No date). Canine communication: recognising stress in your dog. [www document] < https://www.pdsa.org.uk/pet-help-and-advice/looking-after-your-pet/puppies-dogs/canine-ladder-of-communication > (accessed 18/08/2023).

Peck, T. C., Sockol, L. E. and Hancock, S. M. (2020). Mind the gap: the underrepresentation of female participants and authors in virtual reality research. *IEEE Transactions on Visualization and Computer Graphics*, 26, 1945-1954.

Peddie, J. (2017). Chapter 8. Technology issues. In *Augmented reality: Where we will all live*. Springer. p183-289

Peng, X. B., Coumans, E., Zhang, T., Lee, T. W., Tan, J. and Levine, S. (2020). Learning agile robotic locomotion skills by imitating animals. *Robotics: science and systems 2020 virtual conference.* doi: 10.15607/rss.2020.xvi.06

Perry, A., Nichiporuk, N. and Knight, R. T. (2016). Where does one stand: a biological account of preferred interpersonal distance. *Social Cognitive and Affective Neuroscience*, 11, 317-326.

Peters, V., Sottiaux, M., Appelboom, J. and Kahn, A. (2004). Posttraumatic stress disorder after dog bites in children. *Journal of Pediatrics*, 144, 121-122.

PFMA (Pet Food manufacturers Association) (2019) Number of cats and dogs per Household 2019. [www document] < https://www.pfma.org.uk/number-of-cats-and-dogs-per-household-2019 > (accessed: 31/12/2019)

Piccart, F., Dormaar, J., Coropciuc, R., Schoenaers, J., Bila, M. and Politis, C. (2019). Dog bite injuries in the head and neck region: a 20-year review. *Craniomaxillofacial Trauma & Reconstruction*, 12, 199-204.

Podberscek, A. L. (1994). Dog on a tightrope: the position of the dog in British society as influenced by press reports on dog attacks (1988 to 1992). *Anthrozoös*, 7, 232-241.

Podberscek, A. L. and Serpell, J. A. (1997). Aggressive behaviour in English cocker spaniels and the personality of their owners. *Veterinary Record*, *141*, 73-76.

Polgár, Z., Blackwell, E. J. and Rooney, N. J. (2019). Assessing the welfare of kennelled dogs—A review of animal-based measures. *Applied Animal Behaviour Science*, 213, 1-13.

Pongrácz, P., Molnár, C., Miklósi, A. and Csányi, V. (2005). Human listeners are able to classify dog (Canis familiaris) barks recorded in different situations. *Journal of Comparative Psychology*, 119, 136.

Posage, J. M., Bartlett, P. C. and Thomas, D. K. (1998). Determining factors for successful adoption of dogs from an animal shelter. *Journal of the American Veterinary Medical Association*, 213, 478-482.

Psious (2018). How psious can help you overcome your fear of animals. [www document] https://blog.psious.com/en/psi ous-fearofanimals. (Accessed 25/10/2020).

Pugliese, M., Voslarova, E., Biondi, V., Passantino, A. (2019). Clinical practice guidelines: an opinion of the legal implication to veterinary medicine. *Animals*, 9, 577.

Putze, S., Alexandrovsky, D., Putze, F., Höffner, S., Smeddinck, J. D. and Malaka, R. (2020, April). Breaking the experience: effects of questionnaires in VR user studies. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1-15).

PWC (2018) Growing VR/AR companies in the UK: a business and legal handbook. PricewaterhouseCoopers LLP; London, UK.

Quero, S., Nebot, S., Rasal, P., Bretón-López, J., Baños, R. M. and Botella, C. (2014). The use of communication and information technologies in the treatment of small animal phobia in childhood. *Behavioral Psychology*, 22, 257–276.

Rajecki, D.W., Rasmussen, J. L., Modlin, S. J. and Holder, A. M. (1998). Dog bites boy: Judgments of blame and shame. *Anthrozoös*, 11, 66-73.

Rangelova, S. and Andre, E. (2019). A survey on simulation sickness in driving applications with virtual reality head-mounted displays. *Presence: Virtual and Augmented Reality*, 27, 15-31.

Rangelova, S., Decker, D., Eckel, M. and Andre, E. (2018, July). Simulation sickness evaluation while using a fully autonomous car in a head mounted display virtual environment. In *International Conference on Virtual, Augmented and Mixed Reality* (pp. 155-167). Springer, Cham.

Rativa, A. S., Postma, M. and van Zaanen, M. (2019, April). The Uncanny Valley of the Virtual (Animal) Robot. In *International Conference on Robotics in Education (RiE),* p. 419-427. Springer, Cham.

Ratschen, E. and Sheldon, T. A. (2019). Elephant in the room: animal-assisted interventions. *British Medical Journal*, 367, l6260.

Rebenitsch, L. and Owen, C. (2016). Review on cybersickness in applications and visual displays. *Virtual Reality*, 20, 101-125.

Reese, L. A. and Vertalka, J. J. (2020). Preventing dog bites: It is not only about the dog. *Animals*, 10, 666.

Rehn, T. and Keeling, L. J. (2011). The effect of time left alone at home on dog welfare. *Applied Animal Behaviour Science*, 129, 129-135.

Reisner, I. R. and Shofer, F. S. (2008). Effects of gender and parental status on knowledge and attitudes of dog owners regarding dog aggression toward children, *Journal of the American Veterinary Medical Association*, 233, 1412-1419.

Reisner, I. R., Nance, M. L., Zeller, J. S., Houseknecht, E. M., Kassam-Adams, N. and Wiebe, D. J. (2011). Behavioural characteristics associated with dog bites to children presenting to an urban trauma centre. *Injury Prevention*, 17, 348-353.

Reisner, I. (2016). The learning dog: a discussion of training methods. In Serpell (eds.) The Domestic Dog: Its evolution, behavior and interactions with people (second edition), p. 211-226. Cambridge University Press, Cambridge, UK.

Rewkowski, N., Rungta, A., Whitton, M. and Lin, M. (2019 March). Evaluating the Effectiveness of Redirected Walking with Auditory Distractors for Navigation in Virtual Environments. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)* (pp. 395-404). IEEE.

Rezac, P., Rezac, K. and Slama, P. (2015). Human behavior preceding dog bites to the face. *Veterinary Journal*, 206, 284-288.

Riccio, G. E. and Stoffregen, T. A. (1991). An ecological theory of motion sickness and postural instability. *Ecological Psychology*, 3, 195-240.

Riemer, S., Heritier, C., Windschnurer, I., Pratsch, L., Arhant, C. and Affenzeller, N. (2021). A review on mitigating fear and aggression in dogs and cats in a veterinary setting. *Animals*, 11, 158. https://doi.org/10.3390/ani11010158.

Rock, M. J., Graham, T. M., Massolo, A. and McCormack, G. R. (2016). Dog-walking, dog-fouling and leashing policies in urban parks: Insights from a natural experiment designed as a longitudinal multiple-case study. *Landscape and Urban Planning*, 153, 40-50.

Rollett, R., Clancy, R., Taib, B. G. and Mannion, C. (2019). Not a plastic surgeon's best friend: Dog bites an increasing burden on UK plastic surgery services. *Journal of Plastic, Reconstructive and Aesthetic Surgery*, 72, 685-710.

Rosado, B., García-Belenguer, S., León, M. and Palacio, J. (2009). A comprehensive study of dog bites in Spain, 1995–2004. *Veterinary Journal*, 179, 383-391.

Royal Mail (2023) Dog awareness. [www document] < https://www.royalmail.com/personal/dog-awareness > (Accessed: 26/08/2023).

RSPCA (2021). How does the Dangerous Dogs Act affect my dog? [www document] < https://www.rspca.org.uk/getinvolved/campaign/bsl/dda > (Accessed 31/07/2021).

Rugaas, T. (2006). On talking terms with dogs: Calming signals. Dogwise Publishing. Washington, USA.

Ruckenstein, M. (2010). Toying with the world: Children, virtual pets and the value of mobility. *Childhood*, 17, 500-513.
Sachs-Ericsson, N., Hansen, N. K. and Fitzgerald, S. (2002). Benefits of assistance dogs: A review. *Rehabilitation Psychology*, 47, 251-277.
Sacks, J. J., Kresnow, M. J. and Houston, B. (1996). Dog bites: how big a problem?. *Injury Prevention*, 2, 52-54.
Safe and Sound Scheme (No date). Safe and sound award scheme [www document] < Safe and Sound Award Scheme | The Kennel Club > (Accessed 19/01/2024).
Salgirli, Y. and Dodurka, T. (2011). The first report of self-directed aggression in a stray dog in Turkey. *Journal of Veterinary Behavior*, 6, 351-354.
Salman, M. D., Hutchison, J., Ruch-Gallie, R., Kogan, L., New Jr, J. C., Kass, P. H. and Scarlett, J. M. (2000). Behavioral reasons for relinquishment of dogs and cats to 12 shelters. *Journal of Applied Animal Welfare Science*, 3, 93-106.
Sanders, C. R. (1990). Excusing tactics: Social responses to the public misbehavior of companion animals. *Anthrozoös*, 4, 82-90.
Sanders, C. R. (1994). Biting the hand that heals you: Encounters with problematic patients in a general veterinary practice. *Society & Animals*, 2, 47-66.
Santigli, E., Trajanoski, S., Eberhard, K. and Klug, B. (2017). Sampling modification effects in the subgingival microbiome profile of healthy children. *Frontiers in Microbiology*, 7, 184780.
Saredakis, D., Szpak, A., Birckhead, B., Keage, H. A., Rizzo, A. and Loetscher, T. (2020). Factors associated with virtual reality sickness in head-mounted displays: a systematic review and meta-analysis. *Frontiers in Human Neuroscience*, 14, 96. https://doi.org/10.3389/fnhum.2020.00096
Sarenbo, S. and Svensson, P. A. (2021). Bitten or struck by dog: A rising number of fatalities in Europe, 1995–2016. *Forensic Science International*, 318, 110592.
Schalamon, J., Ainoedhofer, H., Singer, G., Petnehazy, T., Mayr, J., Kiss, K. and Höllwarth, M. E. (2006). Analysis of dog bites in children who are younger than 17 years. *Pediatrics*, 117, e374-e379.
Schalke, E. (2017). Best advice to a dog owner whose dog has bitten someone. In Mills, D. S. and Westgarth, C. (eds.) Dog bites: A multidisciplinary perspective. 5m publishing, Sheffield, UK.
Schatz, K. Z., Engelke, E. and Pfarrer, C. (2021). Comparative morphometric study of the mimic facial muscles of brachycephalic and dolichocephalic dogs. *Anatomia, Histologia, Embryologia*, 50, 863-875.
Schilder, M. B., Vinke, C. M. and van der Borg, J. A. (2014). Dominance in domestic dogs revisited: Useful habit and useful construct?. *Journal of Veterinary Behavior*, 9, 184-191.
Schöberl, I., Wedl, M., Bauer, B., Day, J., Möstl, E. and Kotrschal, K. (2012). Effects of owner–dog relationship and owner personality on cortisol modulation in human–dog dyads. *Anthrozoös*, 25, 199-214.
Schubert, T., Friedmann, F. and Regenbrecht, H. (2001). The experience of presence: Factor analytic insights. *Presence: Teleoperators and Virtual Environments*. 10, 266-281.
Schwebel, D. C., Gaines, J. and Severson, J. (2008). Validation of virtual reality as a tool to understand and prevent child pedestrian injury. *Accident Analysis and Prevention*, 40, 1394-1400.
Schwebel, D. C., Morrongiello, B. A., Davis, A. L., Stewart, J. and Bell, M. (2012). The Blue Dog: Evaluation of an interactive software program to teach young children how to interact safely with dogs. *Journal of Pediatric Psychology*, 37, 272-281.

Schwind, V., Knierim, P., Haas, N. and Henze, N. (2019, May). Using presence questionnaires in virtual reality. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-12).

Schwind, V., Leicht, K., Jäger, S., Wolf, K. and Henze, N. (2018). Is there an uncanny valley of virtual animals? A quantitative and qualitative investigation. *International Journal of Human-Computer Studies*, 111, 49-61. doi:10.1016/j.ijhcs.2017.11.003

Shields, L. B., Bernstein, M. L., Hunsaker III, J. C. and Stewart, D. M. (2009). Dog bite-related fatalities: a 15-year review of Kentucky medical examiner cases. *The American Journal of Forensic Medicine and Pathology*, 30, 223-230.

Shen, J., Rouse, J., Godbole, M., Wells, H. L., Boppana, S. and Schwebel, D. C. (2017). Systematic review: interventions to educate children about dog safety and prevent pediatric dog-bite injuries: a meta-analytic review. *Journal of Pediatric Psychology*, 42, 779-791.

Shen, J., Pang, S., and Schwebel, D. C. (2016). A randomized trial evaluating child dog-bite prevention in rural China through video-based testimonials. *Health psychology*, 35, 454.
Shen, J., Rouse, J., Godbole, M., Wells, H. L., Boppana, S. and Schwebel, D. C. (2017). Systematic review: interventions to educate children about dog safety and prevent pediatric dog-bite injuries: a meta-analytic review. *Journal of Pediatric Psychology*, 42, 779-791.
Shepherd, K. (2002). Development of behaviour, social behaviour and communication in dogs. In BSAVA manual of canine and feline behavioural medicine, (p. 8-20). BSAVA, UK.

Shepherd, K. (2009). Behavioural medicine as an integral part of veterinary practice. In Horwitz, D. F. and Mills, D. S. (eds.) *BSAVA manual of canine and feline behavioural medicine* (pp. 10-23). BSAVA, UK.

Sherman, B. L. and Serpell, J. (2008). Training veterinary students in animal behaviour to preserve the human-animal bond. *Journal of Veterinary Medical Education*, 35, 496-502.

Sherman, W. R. and Craig, A. B. (2018). Introduction to virtual reality. In *Understanding virtual reality: Interface, application, and design*. p. 4-58. Elsevier.

Shuler, C. M., DeBess, E. E., Lapidus, J. A. and Hedberg, K. (2008). Canine and human factors related to dog bite injuries. *Journal of the American Veterinary Medical Association*, 232, 542-546.

Siettou, C., Fraser, I. M., and Fraser, R. W. (2014). Investigating some of the factors that influence "consumer" choice when adopting a shelter dog in the United Kingdom. *Journal of Applied Animal Welfare Science*, 17, 136-147.

Silverman, W. K. and Albano, A. M. (1996). Anxiety disorders interview schedule for DSM-IV: Child version. Oxford University Press, UK.

Singh, N. and Malik, M. A. (2014). Risk of dog bite injury in veterinary practice. *Veterinary Record*, 174, 151.

Siniscalchi, M., d'Ingeo, S., Minunno, M. and Quaranta, A. (2018). Communication in dogs. *Animals*, 8, 131.

Sinski, J., Carini, R. M. and Weber, J. D. (2016). Putting (Big) black dog syndrome to the test: Evidence from a large metropolitan shelter. *Anthrozoös*, *29*, 639-652.

Slater, M. (2004). How colourful was your day?. Why questionnaires cannot assess. *Presence*, 13, 484-493.

Slater, M. (2018). Immersion and the illusion of presence in virtual reality. *British Journal of Psychology*, 109, 431-433.

Slobounov, S. M., Ray, W., Johnson, B., Slobounov, E. and Newell, K. M. (2015). Modulation of cortical activity in 2D versus 3D virtual reality environments: an EEG study. *International Journal of Psychophysiology*, 95, 254-260.

Somppi, S., Törnqvist, H., Kujala, M. V., Hänninen, L., Krause, C. M. and Vainio, O. (2016). Dogs evaluate threatening facial expressions by their biological validity–Evidence from gazing patterns. *PloS One*, 11, p.e0143047.

Sorrento, G. U., Archambault, P. S. and Fung, J. (2018). Adaptation and post-adaptation effects of haptic forces on locomotion in healthy young adults. *Journal of Neuroengineering and Rehabilitation*, 15, 1-11.

Sparrow, S., Cicchetti, D. and Balla, D. (2005). Vineland-ii. *Vineland adaptive behavior scales. Survey forms manual. Minneapolis, USA; Pearson Inc*.

Spence, S. H. (1998). A measure of anxiety symptoms among children. *Behaviour Research and Therapy*, 36, 545-566.

Spiegel, I. B. (2000). A pilot study to evaluate an elementary school-based dog bite prevention program. *Anthrozoös*, 13, 164-173.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R. and Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Stanney, K. M., Kennedy, R. S. and Drexler, J. M. (1997). Cybersickness is not simulator sickness. In *Proceedings of the Human Factors and Ergonomics Society annual meeting*. 41, 1138-1142. Sage CA: Los Angeles, CA: SAGE Publications.

Steimer, T. (2022). The biology of fear-and anxiety-related behaviors. *Dialogues in Clinical Neuroscience*, 4, 231-249

Stevens, J. A., Teh, S. L. and Haileyesus, T. (2010). Dogs and cats as environmental fall hazards. *Journal of Safety Research*, 41, 69-73.

Stowers, J. R., Hofbauer, M., Bastien, R., Griessner, J., Higgins, P., Farooqui, S., Fischer, R. M., Nowikovsky, K., Haubensak, W., Couzin, I. D. and Tessmar-Raible, K. (2017). Virtual reality for freely moving animals. *Nature Methods*, 14, 995-1002.

Suárez, A. A., Disdier, S., Cruz, R., Goenaga, M. and Gurabo, P. R. (2017). Virtual reality therapy implementation for zoophobia. In *Proceedings of the LACCEI international Multi-conference for Engineering, Education and TeCHIology*.

Suied, C., Drettakis, G., Warusfel, O. and Viaud-Delmon, I. (2013). Auditory-visual virtual reality as a diagnostic and therapeutic tool for cynophobia. *Cyberpsychology, Behavior, and Social Networking*, 16, 145-152.

Suso-Ribera, C., Fernández-Álvarez, J., García-Palacios, A., Hoffman, H. G., Bretón-López, J., Banos, R. M., and Botella, C. (2019). Virtual reality, augmented reality, and in vivo exposure therapy: a preliminary comparison of treatment efficacy in small animal phobia. *Cyberpsychology, Behavior, and Social Networking*, 22, 31-38.

Sutherland, I. E. (1968, December). A head-mounted three dimensional display. In *Proceedings of the December 9-11, 1968, fall joint computer conference, part I* (p. 757 - 764).

Sutherland, J. and La Russa, D. (2017). Virtual Reality. In: Rybicki, F., Grant, G. (eds) *3D Printing in Medicine*. Springer, Cham. https://doi.org/10.1007/978-3-319-61924-8_12

Svoboda, H. J., and Hoffman, C. L. (2015). Investigating the role of coat colour, age, sex, and breed on outcomes for dogs at two animal shelters in the United States. *Animal Welfare*, 24, 497-506.

Swobodzinski, M., Maruyama, M. and Mankowski, E. (2021). Methodological and institutional considerations for the use of 360-degree video and pet animals in human subject research: An experimental case study from the United States. *Behavior Research Methods*, 53, 977-992.

Taffou, M., Chapoulie, E., David, A., Guerchouche, R., Drettakis, G., and Viaud-Delmon, I. (2012). Auditory-visual Integration of Emotional Signals in a Virtual Environment for Cynophobia. In Wiederhold, B. K. and Riva, G. (Eds.) *Studies in Health Technology and Informatics*, 181, 238-242.

Taffou, M., Chapoulie, E., David, A., Guerchouche, R., Drettakis, G. and Viaud-Delmon, I. (2012). Auditory-visual integration of emotional signals in a virtual environment for cynophobia. In Wiederhold, B. K. amd Riva, G. (eds) *Annual Review of Cybertherapy and Telemedicine 2012*, 238 - 242. IOS Press

Taffou, M., Guerchouche, R., Drettakis, G. and Viaud-Delmon, I. (2013). Auditory–visual aversive stimuli modulate the conscious experience of fear. *Multisensory Research*, 26, 347-370.

Tami, G. and Gallagher, A. (2009). Description of the behaviour of domestic dog (canis familiaris) by experienced and in experienced people. *Applied Animal Behaviour Science*, 120, 159-169.

Tanaka, N. and Takagi, H. (2004). Virtual reality environment design of managing both presence and virtual reality sickness. *Journal of Physiological Anthropology and Applied Human Science*, 23, 313-317.

Tardif, N., Therrien, C. É. and Bouchard, S. (2019). Re-examining psychological mechanisms underlying virtual reality-based exposure for spider phobia. *Cyberpsychology, Behavior, and Social Networking*, 22, 39-45.

Taylor, K. D. and Mills, D. S. (2007). The effect of the kennel environment on canine welfare: A critical review of experimental studies. *Animal Welfare*, 16, 435-447.

Thalmann, O., Shapiro, B., Cui, P., Schuenemann, V. J., Sawyer, S. K., Greenfield, D. L., Germonpré, M. B., Sablin, M. V., López-Giráldez, F., Domingo-Roura, X. and Napierala, H. (2013). Complete mitochondrial genomes of ancient canids suggest a European origin of domestic dogs. *Science*, 342, 871-874.

The Blue Dog (No date) The ladder of aggression. [www document] < http://thebluedog.org/en/dog-behaviour/behaviour-problems/why-does-my-dog/ladder-of-aggression > (Accessed 18/08/2023).

The Kings Fund (2021). Waiting times for elective (non-urgent) treatment: referral to treatment. [www document] https://www.kingsfund.org.uk/projects/nhs-in-a-nutshell/waiting-times-non-urgent-treatment (Accessed 15/11/2021).

Thomas, H. F. and Banks, J. (1990) A survey of dog bites in Thanet. *Journal of the Royal Society of Health*, 110, 173.

Treisman, M. (1977). Motion sickness: An evolutionary hypothesis. *Science*, 197, 493-495.

Trevathan-Minnis, M., Bloom, T., Atlas, N., MacDonald, D. A. and Friedman, H. L. (2021). Using dog facial-emotion recognizability to explore the putative black dog syndrome. *Humanistic Psychologist*, 49, 616–629.

Tsai, Y. F. and Kaufman, D. (2014) Interacting with a computer-simulated pet: Factors influencing children's humane attitudes and empathy. *Journal of Educational Computing Research*, 51, 145-161.

Tulloch, J. S. P., Owczarczak-Garstecka, S. C., Fleming, K. M., Vivancos, R. and Westgarth, C. (2021). English hospital episode data analysis (1998–2018) reveal that the rise in dog bite hospital admissions is driven by adult cases. *Scientific Reports*, 11, 1767.

Tulloch, J. S., Oxley, J. A., Christley, R. M. and Westgarth, C. (2023). Dog-related deaths registered in England and Wales from 2001 to 2021. *Public Health*, 215, 91-93.

Turner, D. C., Waiblinger, E. and Meslin, F. X. (2013). Benefits of the human-dog relationship. In Wandeler, A. I., Macpherson, C. N. L. and Meslin, F. (eds,) *Dogs, zoonoses and public health*. p. 13-23. CABI publishing, Wallingford, UK.

Udry J. R. (1998). Why are males injured more than females? *Injury Prevention*, 4**,** 94-95.

UK Pet Food (2023). UK Pet population. [www document] < https://www.ukpetfood.org/information-centre/statistics/uk-pet-population.html > (Accessed 18/08/2023).

Usoh, M., Arthur, K., Whitton, M. C., Bastos, R., Steed, A., Slater, M. and Brooks Jr, F. P. (1999). Walking> walking-in-place> flying, in virtual environments. In Proceedings of the 26th annual conference on computer graphics and interactive techniques (pp. 359-364).

van Rooy, D. and Wade, C. M. (2019). Association between coat colour and the behaviour of Australian Labrador retrievers. *Canine Genetics and Epidemiology*, 6, 1-7.

Vasser, M. and Aru, J. (2020). Guidelines for immersive virtual reality in psychological research. *Current Opinions in Psychology*, 36, 71-76.

Viaud-Delmon, I., Ivanenko, Y. P., Berthoz A. and Jouvent, R. (2000). Adaption as sensorial profile in trait anxiety: A study with virtual reality. *Journal of Anxiety Disorders*, 14, 583−601.

Viaud-Delmon, I., Znaïdi, F., Bonneel, N., Suied, C., Warusfel, O. and Drettakis, G., (2008). Auditory-visual virtual environments to treat dog phobia. In *The Seventh International Conference on Disability, Virtual Reality and Associated Technologies with ArtAbilitation 2008* (pp. 119-124). ICDVRAT/University of Reading, UK.

Vinci, C., Brandon, K. O., Kleinjan, M. and Brandon, T. H. (2020). The clinical potential of augmented reality. *Clinical Psychology*, 27, e12357.

Virtual Reality Society (2017). What is Virtual Reality [www document] https://www.vrs.org.uk/virtual-reality/what-is-virtual-reality.html (Accessed 20/01/2020).

VIVE (No date). Vive Pro. [www document] https://www.vive.com/uk/product/vive-pro/ (Accessed on 17/03/2020).

Vorstenbosch, V., Antony, M. M., Koerner, N. and Boivin, M. K. (2012). Assessing dog fear: Evaluating the psychometric properties of the dog phobia questionnaire. *Journal of Behavior Therapy and Experimental Psychiatry*, 43, 780-786.

Wagels, L., Radke, S., Goerlich, K. S., Habel, U. and Votinov, M. (2017). Exogenous testosterone decreases men's personal distance in a social threat context. *Hormones and Behavior*, 90, 75-83.

Waller, B. M., Peirce, K., Caeiro, C. C., Scheider, L., Burrows, A. M., McCune, S. and Kaminski, J. (2013). Paedomorphic facial expressions give dogs a selective advantage. *Plos One* 8, e82686. https://doi.org/10.1371/journal.pone.0082686

Wan, M., Bolger, N. and Champagne, F.A. (2012). Human perception of fear in dogs varies according to experience with dogs. *PLoS One*, 7, e51775. https://doi.org/10.1371/journal.pone.0051775

Wang, R., Blackburn, G., Desai, M., Phelan, D., Gillinov, L., Houghtaling, P. and Gillinov, M. (2017). Accuracy of wrist-worn heart rate monitors. *JAMA Cardiology*, *2*, 104-106.

Wang, D., Guo, Y., Liu, S., Zhang, Y., Xu, W. and Xiao, J. (2019). Haptic display for virtual reality: Progress and challenges. *Virtual Reality & Intelligent Hardware*. 1, 136–162.

Watkins, F. and Westgarth, C. (2017). Impact of dog aggression on victims. In Mills, D. S. and Westgarth, C. (eds.) *Dog bites: A multidisciplinary perspective*. 5m publishing, Sheffield, UK.

Wayne, R. K. and Ostrander, E. A. (1999). Origin, genetic diversity, and genome structure of the domestic dog. *BioEssays*, 21, 247-257.

Wayne, R. K. and Vilà, C. (2001). Physiology and origin of the domestic dog. In Ruvinsky, A., and Sampson, J. (eds). *The genetics of the dog*. p1-13. CABI Publishing. UK.

Weber, S., Weibel, D. and Mast, F. W. (2021). How to get there when you are there already? Defining presence in virtual reality and the importance of perceived realism. *Frontiers in Psychology*, 12, 628298.
Wechsler, T. F., Kümpers, F. and Mühlberger, A. (2019). Inferiority or even superiority of virtual reality exposure therapy in phobias?—A systematic review and quantitative meta-analysis on randomized controlled trials specifically comparing the efficacy of virtual reality exposure to gold standard in vivo exposure in agoraphobia, specific phobia, and social phobia. *Frontiers in Psychology*, 1758.
Weiss, A., Wurhofer, D. and Tscheligi, M. (2009). "I love this dog"—children's emotional attachment to the robotic dog AIBO. *International Journal of Social Robotics*. 1, 243-248.
Wells, D. L. (2004). The facilitation of social interactions by domestic dogs. *Anthrozoös*, 17, 340-352.
Wells, D. L. (2017). Behaviour of dogs. In Jensen, P. (eds). The ethology of domestic animals: An introductory text. CABI, Wallingford, UK. p. 228 – 240.
Wells, D. L. (2019). The state of research on human–animal relations: implications for human health. *Anthrozoös,* 32, 169-181.
Wells, D. L, and Hepper, P. G. (1992). The behaviour of dogs in a rescue shelter. *Animal Welfare*, 1, 171-186.
Wells, D. L. and Hepper, P. G. (2012). The personality of "aggressive" and "non-aggressive" dog owners. *Personality and Individual Differences*, 53, 770-773.
Westgarth, C. (2016). Why nobody will ever agree about dominance in dogs. *Journal of Veterinary Behavior*, 11, 99-101.
Westgarth, C., Brooke, M. and Christley, R. M. (2018). How many people have been bitten by dogs? A cross-sectional survey of prevalence, incidence and factors associated with dog bites in a UK community. *Journal of Epidemiology & Community Health*, 72, 331-336.
Westgarth, C., Christley, R. M., Marvin, G. and Perkins, E. (2019). The responsible dog owner: the construction of responsibility. *Anthrozoö*s, 32, 631-646.
Westgarth, C. and Watkins, F. (2015). A qualitative investigation of the perceptions of female dog-bite victims and implications for the prevention of dog bites. *Journal of Veterinary Behavior*, 10, 479-488.
Whitwam, L. (2015). *Which dog breed? The insider's guide*. Canine Handbooks, UK.
Whyte, J. (2007). Virtual reality and the built environment. Routledge, New York, US.
Wiener, P., Sánchez-Molano, E., Clements, D. N., Woolliams, J. A., Haskell, M. J. and Blott, S. C. (2017). Genomic data illuminates demography, genetic structure and selection of a popular dog breed. *BMC Genomics*, 18, 1-13.
Wijker, C., Leontjevas, R., Spek, A. and Enders-Slegers, M. J. (2019). Process evaluation of animal-assisted therapy: Feasibility and relevance of a dog-assisted therapy program in adults with autism spectrum disorder. *Animals*, 9, 1103.
Willmott, H., Greenheld, N. and Goddard, R. (2012). Beware of the dog? An observational study of dog-related musculoskeletal injury in the UK. *Accident Analysis & Prevention*, 46, 52-54.
Wilson, E. O. (1984). Biophilia: the human bond with other species. Harvard University Press. USA. p.1–157.
Wilson, F., Dwyer, F. and Bennett, P. C. (2003). Prevention of dog bites: Evaluation of a brief educational intervention program for preschool children. *Journal of Community Psychology*, 31, 75-86.
Witmer, B. G., Jerome, C. J. and Singer, M. J. (2005). The factor structure of the presence questionnaire. *Presence: Teleoperators & Virtual Environments*, 14, 298-312.

Wolpe, J. (1973). *The practice of behavior therapy (2nd ed.)*, Pergamon, New York.
Wongsaengchan, C. and McKeegan, D. E. (2019). The views of the UK public towards routine neutering of dogs and cats. *Animals*, 9, 138.
Woodward, L., Milliken, J. and Humy, S. (2012). Give a dog a bad name and hang him: Evaluating big, black dog syndrome. *Society & Animals*, 20, 236-253.
WHO (World Health Organisation) (2018). Animal Bites. [www document] https://www.who.int/news-room/fact-sheets/detail/animal-bites (Accessed 11/10/2021).
Yamada, Y., Kawabe, T. and Ihaya, K. (2013). Categorization difficulty is associated with negative evaluation in the "uncanny valley" phenomenon. *Japanese Psychological Research*, 55, 20-32.
Yapan, S., Şimşek, N. Y. and Sütçigil, L. (2023). Effects of augmented reality exposure therapy combined with cognitive intervention on cat phobia. *International Journal of Cognitive Therapy*, 1-28. https://doi.org/10.1007/s41811-023-00169-x
Yeo, N. L., White, M. P., Alcock, I., Garside, R., Dean, S. G., Smalley, A. J. and Gatersleben, B. (2020). What is the best way of delivering virtual nature for improving mood? An experimental comparison of high definition TV, 360 video, and computer generated virtual reality. *Journal of Environmental Psychology*, 72, 101500.
Yildirim, C. (2019). Don't make me sick: investigating the incidence of cybersickness in commercial virtual reality headsets. *Virtual Reality*, 24, 231-239.
Yin, J., Hinchet, R., Shea, H. and Majidi, C. (2021). Wearable soft technologies for haptic sensing and feedback. *Advanced Functional Materials*, 31, 2007428.
Yu, Y., Wilson, B., Masters, S., van Rooy, D. and McGreevy, P. D. (2021). Mortality resulting from undesirable behaviours in dogs aged three years and under attending primary-care veterinary practices in Australia. *Animals*, 11, 493.
Zhan, T., Yin, K., Xiong, J., He, Z. and Wu, S. T. (2020). Augmented Reality and Virtual Reality Displays: Perspectives and Challenges. *iScience*, 23, 101397.
Zilcha-Mano, S., Mikulincer, M. and Shaver, P. R. (2012). Pets as safe havens and secure bases: The moderating role of pet attachment orientations. *Journal of Research in Personality*, 46, 571-580.