DESIGN FOR LUXURY AUTOMOTIVE HMI SYSTEMS AND DRIVER EXPERIENCES

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by

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DECLARATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

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Luxury is predominantly discussed within marketing, economics and psychology literature, with little research made into the practicalities of designing for luxury products and experiences. This thesis addresses the lack of an evidence base from which to design and virtually prototype luxury automotive HMI (human-machine interaction) systems. The work involved five interconnected studies and two industrial partners: Bentley Motors – manufacturers of luxury automobiles; and the VEC (Virtual Engineering Centre) – a consultancy and R&D organization specialising in digital simulation.

In Study 1, a literature review was conducted to build a foundation for the research, providing definitions of luxury and investigating attributes of luxury products, cars and experiences. Four distinct luxury values were identified: financial, symbolic, functional and experiential. Study 2 comprised a benchmarking field study using immersion methods. The HMI system for four luxury cars was analysed to reveal state-of-the-art uses of interaction technologies and control/interaction details. The study provided the researcher with luxury car orientation, whilst uncovering notable tensions in the integration of luxurious design details with advanced interaction and interface technologies.

Study 3 comprised the main field research, seeking to deeply probe drivers' understanding and expectations for HMI systems qualified as providing a luxury experience. Semi-structured in-car interviews were conducted with Bentley Motors employees (n=28). Transcript and video data were processed using grounded theory, verbatim coding and content analysis. The verbatim codes led to a quantitative hierarchy of design criteria for luxury automotive

HMI systems. The content analysis provided an exhaustive collection of user constructs that were qualitatively clustered into maps of luxury automotive HMI system and experience dimensions. In combination, the hierarchical design criteria and construct maps provide a set of guidance to assist designers when conceptualizing luxury HMI system interactions and experiences.

Study 4 implemented the guidance from Study 3 through a project to ideate a set of 3 luxury HMI system concepts, as inspirational materials for Bentley Motors. A review of new, emerging and unusual (NEU) interaction technologies was made to assist the generation of concepts satisfying the luxury principle of rarity. Finally, in Study 5 a workshop with VEC experts established the plausibility of virtual and augmented reality systems to digitally simulate HMI systems using NEU interactive technologies. Study 5 satisfied a need within Bentley Motors for better understanding of how HMI system design and virtual prototyping could align.

The thesis concludes that: (i) user experience goals for luxury automotive HMI systems can be uncovered in a rigorous way through design research; (ii) the design of luxury automotive HMI systems benefits from a new set of a guidance developed from research data without reliance on corporate know-how; and (iii) careful selection of virtual and augmented reality technologies can provide plausible virtual prototyping routes for HMI design concepts.

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LIST OF ABBREVIATIONS

3D	Three dimensional
AR	Augmented Reality
AUTOMOTIVE 3I	Automotive Interiors, Interfaces and Interactions
GHOST	Generic, Highly-Organic, Shape-Changing Interfaces
GUI	Graphical User Interface
HCI	Human Computer Interaction
HMI	Human Machine Interaction
HUBO	Humanoid Robot
HUD	Head Up Display
MR	Mixed Reality
NEU	New Emerging Unusual
OLED	Organic Light Emitting Diode
PneUI	Pneumatically Actuated Soft Composite User Interface
R&D	Research and Development
UoL	University of Liverpool
UX	User Experience
VEC	Virtual Engineering Centre
VR	Virtual Reality
WSD	Wind Shield Display

CHAPTER 1

INTRODUCTION

This PhD project brought together three partners in a programme of research and development: the University of Liverpool (UoL), Bentley Motors Ltd[1] and the Virtual Engineering Centre (VEC)[2]. The research area was defined through a series of planned discussions and meetings with the collaborating bodies based on presentations that were prepared with the results of on-going literature reviews and trend analyses. The overlapping concerns and motivations of the collaborating bodies led to the identification of research to improve automotive interiors, interfaces and interaction designs (automotive-3I) based on the pursuit of luxurious experience in a driving context.

The specific project focus is an investigation of 'luxurious interaction' with automobile human-machine interfaces (HMI), applied to a design task to consider how current driver HMI can be re-organized and re-presented taking into account new interface and interaction technologies.

1.1 Problem Definition

The concept of luxury has played different roles throughout history. Once it was tributes offered to God(s) for their mercy, then it was huge buildings symbolising the power of kings/queens, and then possessions buried with those who have deceased to give them comfort even in an afterlife. Years later, with societal events (liberalisation, democratisation, and women's rights movements, industrial revolution) luxury was interpreted as an unjust way of presenting wealth to others, creating social classifications based on the income of people. However, today luxury is segmented and democratised and has evolved into a subjective concept that is based on individuals' understanding, experience and income. Over the last few decades, the concept of luxury has been redefined, criticised, and recreated by marketers, social scientists, and psychologists through considerable research effort. This

[1] Luxury car manufacturer: "the definitive British luxury car company, crafting the world's most desirable high-performance grand tourers" (Bentley Motors Ltd., 2015)

[2] Research centre specializing in digital simulation and virtual environments: "providing a focal point for leading and emergent virtual engineering technology, research and expertise" (Virtual Engineering Centre, 2015)

research has mainly been based on brand identity and values to create luxury (Kapferer & Bastien, 2009; Wiedmann, Hennings, Klarmann & Behrens, 2013), the effects of luxury consumption on society and society on luxury consumption (Cannon & Rucker, 2019) as well as the motivations of people to consume luxury products (Ki, Lee, & Kim, 2017). Even though design is not the main focus amongst these studies, the research findings still offer valuable insights into the design process where luxury goods are involved.

The four luxury values (financial, functional, experiential, symbolic) defined in marketing literature (Berthon, Pitt, Parent, & Berthon, 2009; Kapferer & Bastien, 2009; Reddy & Terblanche, 2005; Wiedmann et al., 2013) contribute to a fundamental understanding of luxury product design. Those values can be built and explained through design features, for example: (i) financial value that is quite effective in terms of the material choice – whether valuable gems and minerals as well as newly-developed materials requiring R&D investment – that reflects on design decisions, form and production techniques; (ii) functional value that can be created through novel technologies as well as expertise through craftsmanship for perfect functioning; (iii) experiential value explained mainly through the purchase experience such as exclusive shops and polite sale staff, although also including (but overlooked in prior studies) the experience created through using luxury products; and lastly (iv) symbolic value explained through brand image on individuals as well as society generally through sets of icons (logos, colours, symbols) that brands create to communicate themselves.

The definition of luxury car in this study is in line with the 'F' (luxury car) and 'S' (sports car / super car) segments based on the classification by European Commission (European Alternative Fuels Observatory, n.d.). The European Commission classification criteria is dependent on the performance and technology cars offer as well as the factors affecting the consumer decision-making process such as price and brand image. Commercially automobile sector defines luxury through certain properties, such as performance offering fast, powerful, nimble driving experiences to users. Iconic design features such as BMW grilles, or the iconic lines of a Porsche 911 that are carried with the design throughout its years of iteration, also creates a visual familiarity associated with luxury vehicles. In addition to iconic features and performance qualities, most luxury cars are associated themselves with a dream scenario: for example, this can be a challenging driving experience on unique terrains (Bentley Oman's hidden treasures) or being the car of an iconic cinema character (James Bond and Aston Martin) as well as presence at events such as Formula 1, emphasizing performance.

Each of the luxury values can be explained through various product features ranging from material choices to interaction technologies. Product design is also concerned with *non-instrumental* product qualities to create an intended experience for the user (Hassenzahl & Tractinsky, 2006). For the last decades, research on user experience (UX) has been in the spotlight for design researchers, mainly concentrated on the experiences that products offer beyond the objective, physical embodiment of products (Hassenzahl & Tractinsky, 2006). UX is dependent on product qualities and sensorial information directing the user about how to use a product (Alben, 1996) as well as cognitive processes leading to the assignment of meanings to products and the evocation of emotions from products before, during and after use (Forlizzi & Batterbee, 2004, Norman, 2004). For this reason, UX is related with the user (i.e. mood, personality, previous experiences), the context (how a product fits a certain context such as social context, environment) and the design characteristics of the product (i.e. functionality, aesthetics). The scope of UX is flexible in that can be extended to brand experience (including brand identity and positioning) (Desmet & Hekkert, 2007) or can be investigated including service providers (such as the experience of a cell phone including the network provider) (Hassenzahl & Tractinsky, 2006). Defining the components and scope of UX is inevitably product-dependent and directed by specific research questions.

Although user experience with reference to car design is quite wide, UX for luxurious driving experience is limited to a few examples mainly defined by marketing professionals through the aforementioned luxury values. Examples such as the sound of a sports car stimulating desire and brand attachment, or the smell of leather communicating luxuriousness through rarity and uniqueness of that natural material are commonplace. However, these studies and current understanding only scratch the surface of luxury user experience in an automotive context, which requires further definitions and directions if it is to serve as a meaningful and actionable design specification. Luxury derives from the Latin phrase “luxus”, meaning ‘excessive’ or ‘offering more than what is needed’. Marketing professionals (Wiedmann, et al., 2013) claim that luxury needs to offer stimuli regarding all senses, creating a multi-sensorial experience that can be translated into luxuriousness through the design characteristics of a product. Nevertheless, current literature is lacking in terms of defining the descriptors of luxury user experience. Design for luxury still largely depends on intuitive processes of designers to build-up an intended experience for users. The descriptors and the criteria for luxurious experience require deeper investigation and research.

However, defining the descriptors of luxury experience is not the only challenge in working towards a meaningful ‘design for luxury’ approach. The effects of fast-paced technological developments on the realisation of car interiors poses challenges as well as opportunities for luxurious driving experience. It is possible to see that through the evolution of technology adoption in cars, HMI plays an important role in presenting information to the driver in a way that utilizes multiple sensory modalities (e.g. sight, sound, tactility, etc.). However, it is not easy for a firm such as Bentley to keep up with the pace of technological developments, which are far more frequent than the typical four to five-year cycle for a new car. Today we cannot spend a moment away from technology. We are overloaded with information which can potentially be quite useful, but under other circumstances might also be unnecessary and annoying. Moreover, the task of driving is already quite complicated and demanding, requiring the driver to keep attention on the driving activity as well as compensate or respond to other driving-related contexts. Information provided in an in-car environment might be quite beneficial in relation to some driving activities, for example regarding safety, but also it might easily become a distraction. Car HMI systems are equipped with several technologies offering a range of information to the driver. Information presented through the HMI is getting voluminous day by day. Effective presentation of the information is a question for car designers regarding what, when and how to present information to the driver. In addition to the organisation or presentation of this information, the way the user interacts (or could act differently or better) with the HMI system requires a thorough analysis. As technologies have offered more possibilities, so we can observe that the main features, that driver interacts with have gradually evolved from pedals, buttons and knobs to touch screens, air gestures, and audio commands. The developments continue. All these technologies offer new actions and require new abilities as well as place a demand on learning processes to interact with the system. New interaction technologies can transform the drivers' choreography whilst they interact with their cars and questions the muscle memory that drivers have built-up throughout the years.

Visions for in-car interaction and driving experience direct research to an autonomous driving scenario. During the meetings with Bentley, the professionals emphasized on the fact that 'luxury automobiles were offering the ultimate autonomous experience through chauffeured driving' since the beginning of their production. However, another value they offer to their drivers is the performance, speed, handling and as a result the sense of power and control. In addition to chauffeured driving experience luxury brands have also extended their lines with Grand Tourers (GT) emphasizing on the driving challenges and joy. For the last decades, the focus of luxury changed from materialistic and financial characteristics to experience based features and stories. The luxury cars, especially luxury sports cars, offer their drivers the experience of driving in challenging terrains, provide them with performance related features (i.e. sport driving mode, sound of the motor based on the performance). The feeling of control and competence during driving is one of the main ingredients of luxurious sports car experience. Without a doubt, the autonomous scenario is going to shape the future of automobiles however, the driving joy and satisfaction will still be included in the design especially in luxury automobile sector.

Technology and luxury can conflict in terms of the use of materials, and the physical embodiment of details. Technologies offer multi-sensorial experiences as a part of the luxurious interaction with information but also pose new challenges on designers who need to embed these technologies and create flowing car interiors. Luxury in the automotive market is built on traditions and heritage that has been created step by step throughout the years, with some brands proudly associating themselves with certain materials, craftsmanship details, and design decisions throughout their history. However, technology brings materials that are incompatible with this heritage, such as touch screens creating black, flat surfaces prone to marking with fingerprints. These components can easily interrupt the visual continuity and the iconic interiors created with flowing wood that has been established over many years. Technology can also bring subtlety and invisibility to HMI features, which can be a source of opportunity to create flowing interiors. However, disappearing interior elements and details need to be redefined to communicate luxury. Luxury has traditionally offered superior quality and performance, based on manufacturing precision and craftsmanship and also the use of rare materials. For example, interior elements such as buttons and knobs communicating luxury with precise production details and materials may make way for subtle technologies having no requirement for physical controls. As a result, the question evolves to a point of asking how can luxury be communicated through technology? The answer to this question lies behind the as-yet-missing descriptors of luxurious driving experience.

Technologies not only facilitate and change the design of products but also serve as a means of evaluating and designing those products in the first place. The designers can create endless alternatives through generative studies and qualitative research however, this process needs to be followed by an evaluation phase. The evaluation phase is crucial and necessary for automotive industry to understand the effects of the design proposal both from experience and safety perspectives. Simulation technologies have become prominent in product evaluation programmes since they offer 'real-world like' environments and experiences. Especially, in the automotive industry, it is important to test-out a design in such an environment to foresee problems and possibilities before committing to manufacture. Creating these real-life driving scenarios circumstances (e.g. road conditions, weather, diversions) is not only costly and but also time-consuming, even for safety concerns, it is not always possible to test out design in such an environment. However, simulation tools are addressing these problems when they are used effectively and as these technologies are fairly new and developing it still needs to be explored to find feasible ways of using them to simulate various needs and demands. Luxurious driving experiences demand multisensorial interactions and precise simulation, which currently can be mimicked by only a few simulation tools and certainly not in its entirety. Multisensorial interaction is complex, dependent on several variables, even in simulation environments, involving various types of controls, feedback and NEU (new, emerging and unusual) technologies. The driving experience is also quite complex including several contextual elements that can affect experiences both positively and negatively. These complex experiences also require thorough thinking and planning in terms of suitability and availability of simulation tools for different modalities, as well as feasibility in terms of time, effort and cost to build certain driving scenarios in a simulation environment. Even though simulation seems to offer feasible and safe ways to evaluate driving experiences, simulating luxuriousness through those tools needs further research to understand the potentials and shortcomings of simulation tools.

As a conclusion, luxury is in an evolutionary phase and this time the change is driven by new technologies. Technology integration is a challenge for HMI systems to offer new ways of interacting as well as physical embodiment to create harmony between new technologies and iconic interior designs, which have been built on the basis of heritage and craftsmanship. Even though technology seems to challenge the luxury automotive sector, this can easily be turned into an opportunity through research and analysis of potentials of technologies. For this reason, the necessary step towards a fuller understanding of the area is an exploration of luxurious ways of interacting with automotive controls and interfaces to create a fluid HMI experience. Another opportunity for technology integration is the ability to mimic all these experiences in a real world like setting through simulation tools. Use of those tools can offer valuable insights and evaluation environments for prototyping experiences as long as they are designed and planned regarding feasibility and suitability.

1.2 Aim

The aim of the research reported through this thesis was to contribute to the design process of luxurious automotive HMI systems by exploring and understanding luxurious user experiences for the driver, and then creating guidance for the design of new luxurious automotive HMI based on NEU interaction technologies. The guidance would address the aforementioned gaps in the literature and could be used for automotive HMI design processes. Aligning with the exploration and definition of luxurious experience, the research was also planned so as to provide insights into the appraisal process of luxurious automotive HMI through UX studies and virtual prototyping.

To achieve this aim, five work packages - explained in detail in the Chapter 3 – Methodology were devised to obtain the following objectives.

- To understand and explore the concept of luxury, automotive HMI, and the communication of luxuriousness in automotive HMI through an extensive literature review including both academic and web-based sources.

- To understand luxurious automotive HMI through immersion methods, experiencing luxury car interiors by taking personal notes and making evaluations of in-car interaction systems.

- To understand the drivers of luxurious cars and to identify design details stimulating or detracting the feeling of luxuriousness through a set of interviews and qualitative data analysis processes.

- To propose design directions for automotive design processes regarding the achievement of luxurious experiences through driver-HMI interactions, and to exemplify the use of these directions through designing process and proposing design concepts having roots in the research findings.

- To explore the potentials and drawbacks of simulation technologies for evaluating HMI design concepts and obtaining user feedback, and to understand the criteria for fast and / or cost-effective ways of using simulation tools for design concept appraisals.

1.3 Research Questions

Framed as a set of research questions, the work reported in the thesis aimed to follow an explorative process directed at answering the following main (broad) question, clarified through multiple sub research questions. This methodology developed for tackling the research questions is outlined within the Chapter 3 - Methodology.

Main Research Question

How can we design automotive HMI to deliver luxury driving experiences?

Sub Research Questions

SRQ.1 *What are the descriptors of luxurious interaction in relation to automotive HMI?*

- How do people define luxurious HMI in their own cars?

- What kind of design features communicate luxuriousness to the driver in a car?

- How can designers apply NEU (new, emerging, unusual) interactive technologies to car interiors intended to deliver luxurious interaction?

SRQ.2 *How can we devise the design appraisal process for luxurious automotive HMI systems and experiences?*

- What kind of simulation tools are more suitable and effective for appraising in-car interactions?

- What factors should be considered when designing a feasible evaluation environment for appraisals of luxurious automotive HMI?

1.4 Research Impact

The luxury car industry aims to provide an effortless, flowing driving experience. Until now, this experience can be created through craftsmanship and use of high-quality production details aligned to high-performance engine, transmission and other engineered components. However today, technology not only contributes to the performance and production but also to the expression of the intended experience. The role of technology and its fast-paced developments require the luxury automotive sector to evaluate technologies from an alternative perspective, being the means to achieve an intended user experience. Even though luxury is predominantly defined through physical embodiment elements, luxury in terms of technology use is quite vague and in need of descriptors and guidelines addressing designers of the luxury sector. Regarding the fact that car interiors are one of the most complicated interactive spaces including several components that users interact with, it is conceivable that descriptors of luxurious experience with car HMI can be transferred to simpler products in other luxury sectors such as consumer durables or fast-moving consumer goods.

Technology use not only contributes to the user experience but also enables and enhances evaluation of interactive technologies in a fast and cost-effective way. Prototyping is an important phase of the design process to generate user feedback and understand the usage scenario. Today prototyping processes make use of physical prototypes that are useful for gathering user feedback about ergonomic and aesthetic concerns but fall short of effective use for appraising interactions. Even though simulation tools have the potential of being interactive, they have rarely been investigated or applied from the point of view of a designer wanting to generate UX appraisal data. With this research, it is also aimed to explore simulation tools from such a design perspective, to assist in digitally prototyping in-car interactions.

The impact of the research is intended to be felt mainly on the luxury automotive sector, by defining and describing the components of luxurious experience in a clear and actionable manner. However, the definition and descriptors of luxury experience will create transferrable knowledge to other luxury sectors based on the fact that automobiles involve many different interaction and information types. Another impact of the research will be defining the abilities, feasibility and suitability criteria of virtual prototyping in the automotive context, based on simulating NEU (new, emerging and unusual) interaction technologies. These criteria will have impact on simulation professionals, providing a head start for planning VR and AR programmes aiming to effectively evaluate precise interaction details for HMI concepts.

CHAPTER 2

LITERATURE REVIEW

This chapter presents the literature review covering the main areas of interest for the research. This PhD is aiming to identify the descriptors of luxury user experience in relation to automotive HMI (Human - Machine Interaction). Therefore, the concept of luxury, user experience (UX) and automotive HMI are the core areas of research for creating an understanding of the area and defining the gaps and opportunities within the literature. The literature review is carried out with academic sources (e.g. journal articles, conference papers) as well as non-academic sources (e.g. technology blogs, websites of car manufacturers) to keep up with the pace of the technological advancements.

The review starts by creating an overview of the concept of luxury, presenting the diversity of definitions and descriptors in literature and how the concept evolved throughout the historical milestones. UX studies and theories are discussed as another facet of the study, to set up the base of the research design to investigate luxurious UX. The knowledge from both areas of literature is combined and discussed through a set of product examples to illustrate how the concept of luxury reflects on product design, including several examples of luxury products from different sectors. The section concludes with a narrowed focus on luxury within the automotive industry and the creation of luxury values through automotive design.

The review of luxury and UX is followed with an investigation of the literature on automotive HMI: defining the subject of study ‘HMI in an automotive context’, with its core areas and components of interaction. The definitions lead the review to focus on the use of trending interaction technologies in automotive HMI. Regarding the fact that interaction technologies are shaping a vast array of products that we interact with, the discussions continue with reflection of these technologies on in-car interaction and design. After definitions from all the main areas of research covered by the PhD, the review concludes with a series of discussions on the challenges and opportunities within the design of luxurious automotive HMI.

The structure of the literature review is represented in Figure 1, showing the logic and connections between the areas of research. Pooling the findings of the literature review together, several important gaps and opportunities for research are revealed. Moreover, the accompanying review of research theories and methodologies provided guidance on practically how to structure and conduct a study investigating luxurious interaction in an automotive HMI context.

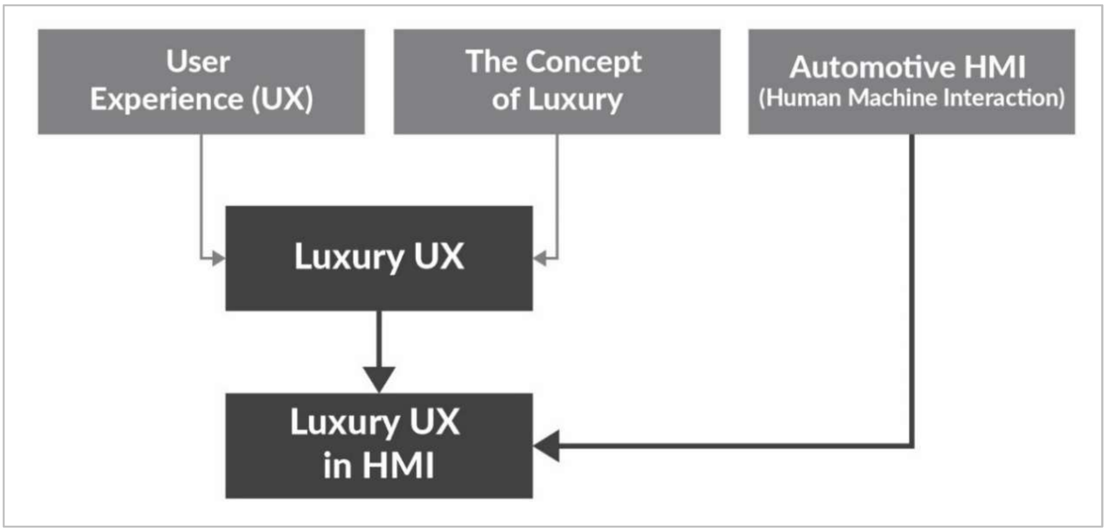

Figure 1. Structure of the literature review

2.1 The Concept of Luxury

Even though luxury has several different definitions, mostly associated with images of rich and powerful people, it is still not easy to create a concrete definition for luxury. It is a "relative term" (Mehta, 2014). For example, a particular car might be luxury to some people whilst to another group of people it may be ordinary, in line with Kapferer's (2012) definition of luxury: "the ordinary of the extraordinary people". Luxury is partially a social concept defined through relationships, therefore throughout history, the definition and scope have been changed with the milestones of sociology, economy, and technology. In order to understand what the concept of luxury stands for in the current era, it is important to track historical changes through time.

2.1.1 Historical Milestones

Most of the terms related to production, marketing and design have changed throughout history because historical milestones trigger social changes reflecting on people's lifestyles and eventually on the definitions of certain concepts. We can trace the concept of luxury back to ancient times, in fact. Kovesi (2015) lists four phases that are effective in the definition of luxury: (i) *ancient world*, (ii) *early modern age*, (iii) *eighteenth century*, and (iv) *the late twentieth century*.

In the *ancient world*, luxury for the Roman Empire is demonstrated mostly through architecture. Elites within society were encouraged to show their wealth through buildings, whilst individualistic pleasures were not accepted as a virtue. However, in Egypt, luxury life was considered to even carry into the afterlife, so that the deceased were buried with their luxury belongings (Kapferer & Bastien, 2009). Another manifestation of luxury can be observed as offering luxury items to god(s) as tributes for their mercy (Kapferer, 2012). During the *early modern age*, benefiting from new trade arrangements, society became wealthier and luxury goods became more accessible. Therefore, sumptuary laws emerged to define the consumption of luxury, banning luxury goods for the ordinary to make them usable for a selected group of people and defining a line between social classes (Kapferer, 2012). Later, in the *eighteenth-century,* society faced a great shake-up, such as liberalisation, democratisation, and women's rights movements. Luxury was debated to be a principal way of distinguishing social classes. However, with the industrial revolution, there was a considerable rise in the living standards of individuals and luxury become more affordable for more people (Kapferer & Bastien, 2009). Lastly, in the *late twentieth century,* there came the democratisation of luxury, making luxury accessible to 'everybody'. Even though such democratisation may seem to distort the original concept of luxury, it brought about a new term of personal luxury or "my luxury" (Kapferer, 2012). Today, societal changes including increased income, delayed marriages, and smaller families, people have more money to spend on their personal luxuries (Silverstein & Fiske, 2003). Thus, a sense of relativity was brought to the term 'luxury', since each social class had its own kinds of luxuries.

Through history, luxury has been interpreted by some commentators as an excessive, unjust way of showing wealth. On the other hand, luxury was a way of supporting improvement and change. Kapferer and Bastien (2009) point out the fact that there will always be debates about luxury, as it is an integral part of other debates such as i) *social stratification*, ii) *the notion of practical utility and waste* and iii) *decisions relating to the distribution of wealth*. As the term luxury is shaped by social changes, it will continue to evolve through time and researchers will continue to investigate what the essential criteria are for luxury products and experiences. The following section sets the scene and lays down criteria that define luxuriousness.

2.2 What Makes It Luxury?

The word 'luxury' has roots from the Latin word *Luxus,* which means 'exceeding growth in agriculture' (Mehta, 2014). Around the 17^{th} century it gained the significance it has today. Although it has strong associations with excessiveness and 'superfluous needs', today luxury has more powerful effects on individuals and society. Featherstone (2014) explains the influence of luxury on people's lives through the power of engaging the senses and offering a range of pleasures.

It is not crystal clear what makes an object luxury as it is a subjective and relative term, but there are research efforts from marketing, psychology and economics aimed at defining the concept. Among the research, marketing focuses on the dimensions of luxury for creating value. Psychological research focuses on the dimensions of people's definition of themselves through luxury objects. Economics focuses on the growing demand for luxury with the changing systems of payment (credit cards, instalments etc.) and how the rise in income of many people will affect the concept of luxury. Dubois, Laurent & Czellar (2001) define luxury through the properties of luxury goods, whilst Vigneron and Johnson (2004) categorise these properties under personal and non-personal titles. Properties of luxury can be understood from both (i) *branding* and (ii) *personal* perspectives.

2.2.1 Branding Perspective

Luxury brands have emerged as a result of the economic growth and expansion of trade traceable back to the industrial revolution. In the nineteenth century, some entrepreneurs built-up companies to produce products targeted at the lifestyle of the social elite of that time (Antoni, Burgelman, & Meza, 2004). Furthermore, with trade possibilities (through advancements in transportation) and the ability to produce in large quantities, these companies expanded their trade to other markets. This provided them the chance to build-up a global reputation over time and to be associated with "superior quality, durability performance or design" (Brun & Castelli, 2013). Nowadays these brands have become symbols of luxury: they not only offer superior quality in their products, but they also have the advantage of a luxury brand image that has been developed and refined over years.

Social and economic changes have demanded that luxury brands update themselves and evolve through this process. They have needed to differentiate themselves and expand their product ranges from time to time, but also to re-define luxury in various ways to remain one of the ‘selected few’. Factors building and updating luxury perception from a marketing point of view are listed through the research of Dubois et al. (2001), Vigneron and Johnson (2004) and Wiedmann, Hennings & Siebels (2009) as: (i) *very high price*, (ii) *scarcity and uniqueness*, (iii) *ancestral heritage and personal history*, and (iv) *superfluousness*.

The respondents of the study by Dubois et al. (2001) pointed out that luxury objects’ prices are very high in comparison with non-luxury objects and *very high price* is perceived as an indicator of luxury. Moreover, expensiveness is also associated with and justified through excellent quality through the use of rare materials, durability and product lifetime. The lifetime of ‘excellent quality’ is longer than expected of non-luxury products, which contributes to trust, comfort and wellbeing. However, Vigneron and Johnson (2004) discuss *very high price* under the *conspicuous consumption* title – that is, having and using luxury brands closely linked to social representation and position. Through their pricing policy, luxury brands are realistically available to only a small group of wealthy people, to whom those brands become indicators of social status. Non-luxury brands try to reach as many customers as they can through stores, events, advertisements etc., whereas luxury brands are sought-out by the customer. Use of pricing, distribution or limited editions etc. can contribute to the creation of exclusivity that is defined as “like accessing to a parish” by Grigorian, Pernod & Petersen (2014).

Scarcity and uniqueness are other concepts associated with luxury objects. These concepts can be linked to the excellent quality that can be achieved by the use of rare, high-quality materials in production, combined with highly skilled craftsmanship. Uniqueness enhances one’s self-image, which is about having a tailor-made experience, specific to one’s personal requirements: “the exclusiveness” (Vigneron & Johnson, 2004). These tailor-made experiences, involving rarity in terms of materials, craftsmanship etc., also command very high prices that make luxury goods inaccessible to most of society. Furthermore, products might be a part of a ‘limited-edition’, making them even harder to be reached (Vigneron & Johnson, 2004). The concept of *scarcity and uniqueness* is not only about quality and price but also the presentation of a luxury product. The design, atmosphere of the shop that the product is presented in, as well as the interaction with the salesperson, are additional factors communicating the exclusivity. The unique experience that people have during purchases makes them feel the benefit of luxury as a sense of refinement and wellbeing. Dubois et al. (2001) explain this simply as: “people do not expect luxury objects to be found in the supermarkets”, whilst Grigorian et al. (2014) define the retail spaces for luxury goods as “beyond a point of sale, a temple”. The Le Labo (Figure 2), a perfume producer, creates such experiences during purchases by producing its perfumes in front of its customers. The experience becomes more like a ritual, offering customers a unique, exclusive experience by also including their name on the perfume bottles (Adams, 2013). Luxury is not only about the brand. Rather, it is about building a consistent experience by blending the brand, the presentation of the product or service, and the qualities of the product or service itself.

Figure 2. The Le Labo Perfume Experience

Alongside brand names and product/service presentation, it is important to create a set of icons for conveying luxury. The identity and communication of luxury brands extends beyond a logo, by creating several iconic visuals in line with the brand image. Grigorian et al. (2014) give the example of Chanel: apart from the logo of intertwined C’s, the brand is also associated with the “little black dress” and even with “the number five”.

Ancestral heritage and personal history are other strategies to build a luxury perception from a branding perspective. Luxury brands re-tell their story to keep their heritage alive. The dream that a luxury brand creates is nurtured by the heritage, the stories, myths, and legends that the brand offers. The consistency within these elements feed into the luxury perception of a brand. Kapferer (2015) interprets this as “luxury represents the future of tradition”. The heritage and history of those brands are maintained through (i) *true history,* (ii) *re-appropriation of true historical elements* and (iii) the *creation of new contemporary legend* (Kapferer & Bastien, 2009).*True history* is the real history: authentic stories of the brands. Kapferer and Bastien (2009) exemplify this with Veuve Clicquot, founded in 1772 with a long tradition. The firm keeps its history alive (based on their founder Madame Clicquot, a French businesswoman) through their prize for ‘*the female entrepreneur of the year*’ offered every year. *Re-appropriation of true historical elements* is exemplified through ‘Dom Pérignon’, which is a relatively young brand for champagne but which borrows a story from Pierre Pérignon (1665, who created the effervescent wine) and builds its narrative upon that

(Kapferer & Bastien, 2009). *The creation of a new, contemporary legend* (Kapferer, 1990) can be exemplified by Ralph Lauren offering *The Great Gatsby* style clothing for attaining the American dream (Kapferer & Bastien, 2009).

Luxury brands become ‘whole’ when combining their icons, values and stores that follow the design principles inspired by mythical heritage elements, such as with Chanel keeping the story and style of Coco Chanel. Kapferer and Bastien (2009) look from another perspective, interpreting a luxury product as a small fragmentation of the culture that it is produced in. So, the production location of the product also becomes a part of its identity, history and heritage, as in the example of Swiss watches. Another way of communicating heritage is exemplified by Grigorian et al. (2014) through BMW World (Figure 3) in Munich. BMW defines the experience they offer in BMW World as “Experience the history of a global brand, new visions for tomorrow and the future of mobility” (BMW-Welt, 2019).

Figure 3. Images from BMW World Munich

Luxury still somehow keeps the meaning of being excessive, useless and *superfluous* from its root word ‘luxus’. *Superfluousness* can be identified as a property of luxury objects offering something so beyond functionality that it can be considered not necessary to be there. Certainly, objects do not need to have functional attributes to be perceived as luxury, but they need to have some excessive qualities offering more than functionality, as in the examples of jewellery or perfumes. Kapferer and Bastien (2009) explain *superfluousness* through the example of surgery, which under normal circumstances is carried out only when necessary and to many people would be perceived as the opposite of luxury, being directly concerned with health issues. Nobody would like to have operations without any urgent reason because it is not a pleasant experience. However, the niche of cosmetic surgery, sometimes marketed through the dream of becoming or staying young forever, is not a necessity in terms of health and may be considered a luxury and superfluous regarding its position.

In addition to dimensions of luxury from a branding perspective, we can also explain the concept through a personal perspective: individuals' interpretations of luxury. Luxury is related to materialisation, design and multi-sensorial experiences, as well as personal or social interpretations. The personal perspective, including how people position themselves in society through luxury, is explained in the following section.

2.2.2 Personal Perspective

Vigneron and Johnson (2004), Dubois et al. (2001) and Kapferer (2012) define luxury as a *hedonistic* experience, involving people's definition of their own luxury experience through pleasure and emotions instead of functional and performance-related benefits. Kapferer (2012) summarises this as the aesthetics of all kinds, using the examples of a fabric used in a dress that does not have to be so comfortable, or the sound of a sports car that can be annoying most of the time, but nevertheless still tied to an emotional satisfaction that people would like to experience. Luxury offers a multi-layered experience that stimulates all senses in different levels, creating a unique blend of stimulations. One of the most famous watches of Patek Philippe, the Star Caliber 2000 produced for the millennium as a limited edition, has particular features to attract people's attention in addition to the use of quality materials and obviously high-quality design. Being the third most complicated mechanical watch (Patek Philippe, 2015), the Star Caliber weaves a story about the history of timekeeping, displaying the movements of the sky with sunset, sunrise, stars and the moon. Another aspect is its auditory interaction, which plays the original Westminster Chime melody in quarter hours and full hours, serving as a remembrance of 'the aristocracy': one of the words used to define the design principles of the brand. This is an example of a luxury brand going beyond functionality and quality to offer personal sensations and dreams to attain to its users.

Vigneron and Johnson's (2004) study showed another face of objects, becoming an *extension of self* for consumers. Consumption of luxury products is not only a self-centred process, but it also involves a comparison of oneself to others in the society. Defining their identity through society, people have references from their surroundings, get influenced, attracted or even sometimes dictated by society. The objects people possess, buy, and use, as a part of their identity, become an indicator for social acceptance. Kapferer and Valette-Florence (2016) ask a question about Louis Vuitton: whether it is luxurious because of its exclusivity and uniqueness regarding materials and hand-crafted features, or whether it is luxurious because it embodies the taste of elites. Today, brands offer their iconic position as a value in addition to the quality attributes of their products. The brand logo, icon or symbol of owned products makes a statement about our own social position and we make statements through exposing them to others. Kapferer and Bastien (2009) define this exclusivity through statements such as “I am the only one owns this” and “this, excludes others”. However, by trying to distinguish themselves from a group of people (the ‘masses’) by differentiating their consumption habits, people inevitably end up getting closer to another group of people (the ‘privileged’).

In both the branding and personal perspectives, luxury experiences are created through a set of values that are explained in studies within the field of marketing (e.g. Berthon et al., 2009; Kapferer & Bastien, 2009; Reddy & Terblanche, 2005; Wiedmann et al., 2013). Those values, even though they are named slightly differently in different research, can be listed as: (i) financial value, (ii) functionality or functional value, (iii) symbolic or social value, and (iv) experiential-individual or personal value. However, before going into detail into these values, it is crucial to understand the perspective of user experience (UX): how people evaluate products and their resultant experiences, giving explanation of those values with product examples focusing on the product features.

2.3 User Experience

We are surrounded by multiple products offering the same functions to us, yet still we can easily spot the one product from this variety that will fit and serve to us personally. Several factors affect our decisions, ranging from functional properties to emotional attachment to certain brands. Regarding this, we can see the fact that products offer more than just their functionality or physical comfort to us – we engage with them in a variety of ways. User experience (UX) research focuses on these latter factors more than utilitarian or usability factors. UX research has over the years developed a range of theories and dimensions defining user experience, as well as offering research methods for the systematic study of UX.

2.3.1 Definitions of User Experience

The term ‘experience’ in a design context was initially defined by Alben (1996), as all the dimensions of how people use an interactive product. Those dimensions can be summarised as how understandable the product is, how well it fits a certain context and purpose, and how the user feels when interacting with that product. For the last few decades, there have been several studies to overcome ambiguities in the definition of UX. Experience is a multifaceted phenomenon by its nature since it is “dynamic, complex and subjective” (Buchenau & Fulton Suri , 2000), dependant on perception and interpretation of the sensorial qualities of a design in relation to the contextual factors. Sanders (2001) emphasized the fact that our experiences last only in *the moment* and become interwoven with our past experiences (*memory*) as well as future expectations (*dreams*). Therefore, researchers claim that experience is *in* people (Sanders, 2001; Batterbee, 2004; Fulton Suri, 2003). Experience is subjective, which is why it cannot be directly designed. Instead, designers can realistically design *for* a particular experience to come about during product use and interaction. Forlizzi and Battarbee (2004) classify experience into three types: (i) *experience*, (ii) *an experience*, and (iii) *co-experience*. *Experience* is about the ongoing activities that we carry out repeatedly to achieve certain goals such as, doing the housekeeping. *An experience* is a finite episode of doing something – it has a beginning and an end and can create behavioural and emotional changes in a person, such as a dinner party or watching a movie. Finally, c*o-experience* is the experience created socially or shared with others, such as playing games with friends, or interacting with others in an exhibition.

As mentioned, experience in a product design context relates to all aspects of experiencing a product — physical, sensual, cognitive, emotional, and aesthetic (Forlizzi & Batterbee, 2004). Hassenzahl and Tractinsky (2006) attempted to explain the unique aspects of UX, differentiating the concept from ‘usability’ through a compilation of studies. The main focus of usability studies is on the *behavioural goals* within a task-oriented approach to evaluation, whereas UX focuses *beyond the instrumental* aspects of design, considering the needs and values of users and the meanings that become associated with product use and interaction. Through their paper, Hassenzahl and Tractinsky (2006) revealed overlapping concepts from the compilation of studies and identified three facets of UX: (i) *users' internal state* (i.e. mood, needs), (ii) *characteristics of the designed system* (i.e. complexity, functionality) and (iii) *the context* (i.e. social setting, the environment).

A further attempt was made by Law, Roto, Hassenzahl, Vermeeren & Kort (2009) to understand and give scope to UX through a survey of 275 researchers and practitioners. They reached a consensus on the fact that UX is affected by the social context but even within that context, UX remains subjective and individual. The definition of UX can be stretched to include *brand experience,* defined as users' relationships with brands. On the other hand, UX can be constrained to *product experience* (Desmet & Hekkert, 2007), excluding services that are often present and affecting the experience (e.g. a mobile phone experience cannot be holistically evaluated if the services and applications of the mobile network provider are excluded). There are still fuzzy areas defining UX, resulting in nuances in interpretation by researchers and practitioners. However, it is generally agreed that UX is context-dependent, dynamic, subjective, and affected by various features of products through sensorial qualities.

The definitions of UX provided by the mentioned researchers revealed the key elements and general framework for subsequent UX researchers to build their own more specialist research. The following section is based on certain theories and models attempting to define in more detail the dimensions of UX.

2.3.2 Dimensions of User Experience

Even though there are disagreements regarding the scope and focus of UX, certain theories have become building blocks for UX studies in a product design context. On a very broad level, Forlizzi and Battarbee (2004) classified three general models of UX: (i) *product-centred models* (providing applications directly for design practice), (ii) *user-centred models* (helping designers to understand their users), and (iii) *interaction-centred models* (that products serve in bridging the gap between designer and user). However, there are also studies covering a wider perspective and aiming to provide a unified UX model. For this thesis, an explanation will be given for a few prominent studies of UX, so as to understand qualities of UX and give some indications about what may be the focus of attention when defining dimensions of luxury user experience.

Jordan (2000) in his book, focusing *beyond the instrumental* attributes of products, linked user experience with the concept of 'the pleasure'. He explains experience through four pleasures, namely: (i) *physio-pleasure* – sensory experiences with products and their physical effects on the user; (ii) *pyscho-pleasure* – cognitive and emotional reactions to products; (iii) *socio-pleasure* – relationships (i.e. society, brands); and (iv) *ideo-pleasure* – moral, ethical values (ideologies, religion). Jordan (2000) concludes his book by emphasising the fact that "people are more than just 'users', they have hopes, dreams, aspirations …" and that these individual factors are also influential in their experiences with products.

Norman (2004) explains UX with products through three levels of processing: (i) *visceral level* - rapid judgements through sensory information; (ii) *behavioural level* – analysing the situation, acting accordingly and building up muscle memory; and (iii) *reflective level* - users' thoughts and reflections depending on their previous personal experiences. With this explanation, it is the interplay between the three levels that creates UX. In a design context, Norman (2004) links the visceral level with the appearance of products, the behavioural level with the pleasure and effectiveness of product use, and the reflective level with self-image, personal satisfaction and memories. Even though these properties seem to be straightforward, Norman (2004) emphasizes the individuality of experience. Exemplifying at the *visceral level*, blue may be an attractive colour for some people, but it may look unpleasant for others; at the *behavioural level,* even though people share similar body shapes we differ in our dexterity and abilities; and at the *reflective level,* we all have unique personalities and personality traits, highly studied by psychologists (Digman, 1990; Goldberg, 1993) ranging from openness to neurotism, affecting our interpretation of things and activities.

In a more inclusive approach, Desmet & Hekkert (2007) explain ‘product experience’ as a term referring to all types of interaction between a user and a product, including *instrumental interaction* (using, operating a product), *non-instrumental interaction* (not function-focused, such as playing with a product), and *non-physical interaction* (remembering or anticipating the interactions). In their framework of product experience, they define a product appraisal process through three factors: (i) *aesthetic experience* – sensory impact of the product (i.e. looks beautiful, sounds pleasant, nice touch sensation), (ii) *experience of meaning* – retrieval of memories and associated meanings (i.e. products can be interpreted as luxurious regarding their properties), and (iii) *emotional experience* – individual and cultural context (i.e. desire for a luxury car, joy through the mobile phone connecting us with friends). Furthermore, these three types or levels of experience do not occur in isolation and are not experienced one-at-a-time, but instead they have interrelations and can stimulate each other. For example, we can experience the desire to buy a luxury car as a result of the meaning we have already assigned to the car; or we can feel pleasure and attachment to a keyring because its texture might be pleasant to interact with. We might attach a meaning of exclusivity to aesthetically pleasing objects and that in turn might trigger a feeling of desire. Finally, in their attempt to explain factors that affect experience, Desmet & Hekkert (2007) point out the role of the user (individuality of experience that is dependent on personality traits as well as the culture) and of utilitarian properties of products (usability – the ability of the product to serve the intended function).

Hassenzahl (2010) adopts a more goal-oriented approach to explaining UX based on activity theory (Kaptelinin & Nardi, 2009), defining UX through: (i) *motor-goals* – how does the user fulfil a goal? (ii) *do-goals* – what does the user want to achieve? (iii) *be-goals* – why does the user want to achieve a goal? In the scenario of keeping in touch with people remotely, the experience of 'making a call' would according to Hassenzahl's explanations fall under the *motor-goal* of the user – it is the practical matter of using a mobile phone or VoIP call, for which different motor abilities are needed. The, *do-goal* in this scenario can be identified as making the call, which is independent of the products or actions and focuses solely on what the user wants to achieve from the call. Lastly, the *be-goal* in this scenario is more abstract and personal, defining the underlying motivations of the user for making a call in the first place. Hassenzahl (2010) emphasizes the importance of *be-goals* for designing for experience and explains more about be-goals by relating them to the ten basic human needs (Sheldon, Elliot, Kim, & Kasser, 2001): autonomy, competence, relatedness, self-actualisation, security, luxury, popularity, physical thriving, self-esteem and pleasure. These basic human needs can fall within the main frame of designers aiming to create fulfilling objects that deliver high quality UX.

All of the aforementioned models, classifications and theories aim to define dimensions of UX from the perspective of users, products (objects) or the user-product interaction itself. However, there are also other studies taking a wider perspective for defining UX. With this wider perspective, some models consider the temporality of UX, taking UX as a time/phase dependent phenomenon, which moderates the nature and intensity of our experiences with products. In her paper, Roto (2007) emphasizes several phases of UX that occur through the process of interaction: (i) *expected interaction,* where even before interacting with a product user has expectations about it through sensory stimulation such as smell, colour…etc.; (ii) *beyond interaction*, where outside effects beyond the interaction process have an influence on our interactions, such as the news that we hear or movies that we see our product used in; and (iii) *during interaction,* being the phase that users interact with the product, which in itself is influenced by the components; user, context and system. Similarly, Karapanos Zimmerman, Forlizzi & Martens (2009) defined phases of experience as: (i) *orientation*, (ii) *incorporation* and (iii) *identification*. The UX process initially starts with *anticipation,* during which the user anticipates and expects a certain type of experience before actually experiencing the product. The initial step of experiencing a product is defined as *orientation,* concerning users' initial experiences with the product – which can result in disappointment or excitement depending on the *novelty* or *learnability* of the product features. The second step of experiencing is *incorporation,* during which the product becomes meaningful in users' daily lives and the focus becomes on *usability* rather than *learnability* of the product features. Finally, is the *identification* phase, in which the product becomes an integral part of users' lives, participating in our social interactions and becoming a part of our self-identity (differentiating or becoming part of a community).

To summarise, Jordan (2000) focuses on pleasures with products, whereas Norman (2004) discusses experience through the levels of human processing of information. Desmet and Hekkert (2007) emphasize the product appraisal process regarding aesthetics, emotions and meanings. Karapanos, et al. (2009) converted their focus to time, and how experiences are developed over time. Hassenzahl (2010) defined experience through the psychology literature, focusing on achievnig basic human goals through the use of products. Roto, Law Vermeeren & Hoonhout (2011) created a white paper that summarises user experience studies. User experience is a complex research area, since it can be limited or stretched based on research intentions. However, UX in a luxury context, requires an understanding firstly of the concept of luxury (as outlined earlier in this chapter) and then how luxury can be created and experienced through products. For this reason, the following section focuses on luxury values and how those values are created through product features.

2.3.3 Product Experience and Luxury Values

User experience is created through several processes however, there is no certain methodology for understanding and designing for luxury experience. As the aforementioned luxury literature explains – mainly nurtured by marketing papers – the creation of luxury is tied strongly to the different kinds of values that luxury products have. Marketing literature points out four basic values on the way to creating a luxury experience: (i) *financial value*, (ii) *functionality or functional value*, (iii) *symbolic or social value*, and (iv) *experiential-individual or personal value* (Figure 4).

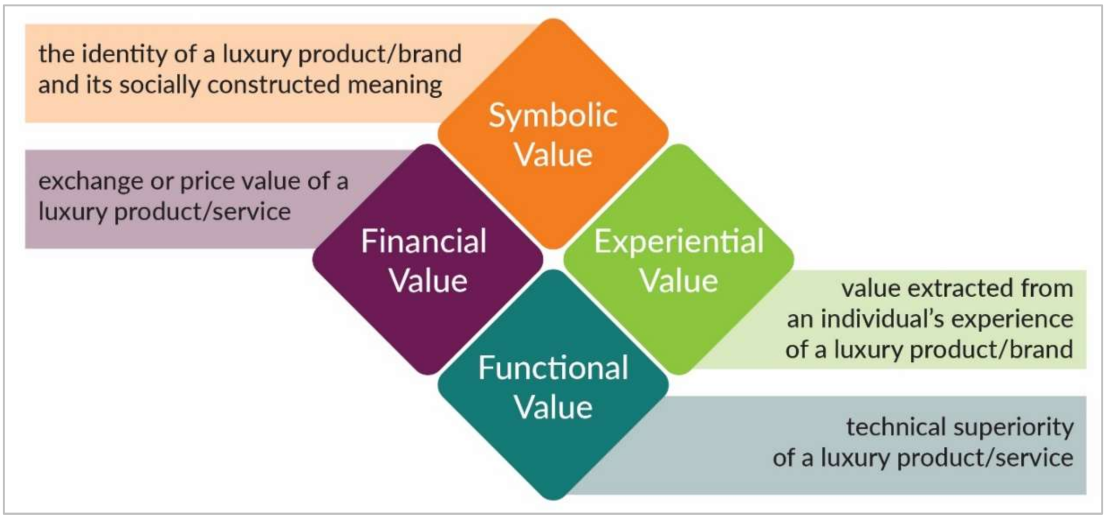

Figure 4. Luxury values (Yardim Sener, Sen, Pedgley, Sener, & Murray, 2016)

In this section, the main aim is to understand each of the four values of luxury and link those values with product features, to build-up an understanding of the relationship between product experience and luxury values.

2.3.3.1 Financial Value

Financial value is straightforward in that it is directly linked with the price of a product (Ahtola, 1984). The retail price of a luxury product can be set regarding several product features including valuable materials or embodied technologies. Oakley (2015) exemplifies that with luxury watches: some have a high retail price due to the use of valuable gems, such as the Rolex Pearlmaster, whereas other watches obtain their price with high technology processing of materials including carbon fibre and lithium titanium alloys, used for example in the Richard Mille RM 027 (Figure 5).

Figure 5. Rolex Pearlmaster 39 (left), Richard Mille RM 027 (right)

Financial value is not only related to the point of sale price, but it can also be gained through the passing of time and it can be about the investment value (as an art object getting more valuable in time) (Wiedmann et al., 2009). Luxury objects are intended to become timeless through careful design decisions, such that a Louis Vuitton suitcase could endure harsh conditions through time and age gracefully with its durable materials, which consequently become 'vintage' (Kapferer & Bastien, 2009). Also, a new car generally loses substantial financial value as soon as it leaves the showroom, whereas a Ferrari would become even more valuable after years with its timeless style (Kapferer & Bastien, 2009). Sometimes, luxurious objects can become a piece of art; symbols of human creativity throughout time. The concept of timelessness can be observed through craftsmanship with high-quality, durable features of luxury objects. Moreover, since they are used over a longer time, the attachment between the product and user becomes stronger and objects become companions of people throughout time. Furthermore, with this attachment, objects become more financially valuable and have more worth when inherited by future generations. Montblanc defines this as its master craftsmen's souls subsequently becoming part of your unique tale, "creating an invisible bond between our soul and yours" (Montblanc, 2015).

2.3.3.2 Functional Value

Luxury is mostly associated with hedonic qualities more than functionality however, it would be strange to define luxury objects without reference to their functional attributes. Even when purchasing non-luxury products, users expect those products to work as promised. But when attention is turned to luxury products, the expectation is of perfect functioning and service during use. Wiedmann et al. (2013) list the core benefits of functional value as quality, uniqueness, usability, reliability and durability. The concept is mostly associated with perceived qualities and is highly related to the ‘ingredients’ of the product materialization and details used in production. Ingredients do not have to be directly about materials; they can also be about, but not limited to, technology, engineering, design etc. Having such refined details necessitates craftsmanship and expertise. Another important feature coming as a result of the ingredients and expertise is trust, regarding the expectation of users to be provided with durability and reliability. As a luxury brand, Patek Philippe explains quality in relation to craftsmanship and the heritage of producing watches for decades. On the other hand, innovation is another point that Patek Philippe emphasizes, with 80 patents about watchmaking (Patek Philippe, 2015).

Reddy and Terblanche (2005) exemplify functional value through Porsche cars, which has built its identity through technical superiority. The corporate communication on their web site under the Porsche Principle title is “always get the most out of everything …. We call it ‘Intelligent Performance’” (Porsche, 2018). Another example is the Mont Blanc M, which is a stylish pen designed by Marc Newson for Montblanc – a watch, writing instruments, jewellery and leather producer. The pen is designed with fine materials described as black ‘precious’ resin and a platinum cap. Montblanc claims to offer products “crafted to withstand the passing time”, which witnesses its owner’s stories through time.

2.3.3.3 Symbolic Value

Symbolic value is the meaning that is attached to luxury products and services through experiences. There are two facets of symbolic value: (i) the meaning built by the brand to communicate its identity to society and (ii) the meaning built socially and associated with the consumers of luxury products. Berthon et al. (2009) exemplify this as: “…a Ferrari may signal wealth, prestige, and performance, and it can be used to constitute and reinforce the owner’s self-image as well.”

A brand’s symbolic value might be created through prestige, heritage, craftsmanship, quality, expertise or many other attributes of the products or branding strategy. Therefore, brands can build unique strategies for creating their symbolic value and position. For example, Patek Philippe, the luxury watch producer, explains its products as follows: “it has been finished by hand by a dedicated, trained specialist, with skills passed down through generations” (Patek Philippe, 2019), emphasizing craftsmanship and quality of production. On the other hand, Rolex prefers a different strategy, associating their brand with challenging journeys for "exploration of the planet's most extreme frontiers and pushing the limits of human endeavour" (Deepsea Challenge, 2012). Recently Rolex demonstrated the superior quality and durability of their 'Rolex Deepsea Challenge' model by joining James Cameron in "his journey to the deepest place on earth" (2012). As mentioned, luxury products become a fragmentation of the culture that they are built in (Kapferer & Bastien, 2009). Therefore, geographic location can become part of the strategy for creating symbolic value. Along with many Swiss watchmakers, Frédérique Constant produces its watches in Geneva – a city which has inherited a major role in the watchmaking industry since the 18th century (Figure 6).

Figure 6. Frédérique Constant watch and fine manufacturing process in Geneva, Switzerland (Frédérique Constant, 2015)

These strategies are examples of creating symbolic value from a branding perspective; how brands link themselves with luxury experiences. However, the symbolic value has another facet that is created through social consumption: people become a member of a certain group through ownership of luxury products (Kapferer & Bastien, 2009). People use luxury products to make a statement about their self-image, wealth, prestige, *au courant* taste to others (Vigneron & Johnson, 2004). Symbolic value can be said to have two facets. One is constructed by the brands – that is, creating symbolic value through narratives, associations with locations, celebrities, challenging events, etc. The second is socially constructed – that is, people recognise luxury brands through their narratives, internalise the scenarios built by them and express themselves through these products or associate luxury consumers with these narratives.

2.3.3.4 Experiential Value

Experiential value is based on the individual interpretations of luxury, through personal (first-hand) experience of the user with luxury products. Experience is created through physical, sensual, cognitive, emotional and aesthetic properties of products (Forlizzi & Batterbee, 2004). In addition to product-specific properties, the "design and identity, packaging and communication" (Berthon, et al., 2009) contribute to the process of building luxury experience. The consumption of luxury products is a search for an "authentic experience, almost art of living" (Kapferer & Bastien, 2009), a way of self-expression through the singularity of the products with their exclusive properties.

Experiential value is subjective and individualistic depending on the values, cultural background, and personal aspirations of the user. For example, a Bang and Olufsen speaker might mean high-quality sound management for one user whereas another user might appreciate its distinctive design, materials and production details. Another example is the Montblanc M pen (Figure 7), which offers a range of experiences such as the 'iconic' sound of its cap, comfortable writing, the alignment of the cap with the body, and its logo which appeals to different customers' varied desires.

Figure 7. Montblanc M Pen (Montblanc, 2015)

Like all products, luxury products cannot be evaluated in isolation since they exist and are experienced within a social setting. Wiedmann et al. (2013) explain the experiential value of luxury not only in relation with materialistic and hedonic attributions of products but also by strengthening one's self-identity, differentiating oneself from others through a "discreet elitism" (Kapferer & Bastien, 2009). Experiential value is woven through the physical embodiment of the product, its design details, as well as the brand and presentation of the product. This can be explained through the previous example of Le Labo, which offers a ritual of perfume preparation to its customers, ending with a scent named after them in their special bottle.

2.3.3.5 Relationships Between Four Luxury Values

Luxury value is created as a combination of four component values. Each brand will have its own unique blend for value creation. Even so, all values have their own characteristics to distinguish themselves from others that they also interact with. Those values can support and contradict with each other, or they can be tied to each other through a cause and effect relationship. For example, *financial value* results in a high retail price, contributing to the *symbolic value* through the availability of the product to a selective group of people and becoming a symbol of wealth. As mentioned, financial value can be created through the use of valuable gems on products, which in turn can contribute to *symbolic or experiential value*. However, *functional value* can also be created through novel technologies or high-quality materials eventually supporting the product. This can also be turned on its head, such that *experiential value* is created through the use of precious gems*, symbolic value* is created through rarity or *functional value* through novel technologies, and investment in research, development and expertise can result in a high *financial value*.

Luxury products are expected to offer exceptional *functional value.* If a product cannot fulfil its function it certainly cannot offer a desirable experience and as a result, it cannot create the *experiential value* expected for a luxury product. For example, certain products such as luxury cars – owing to their superior quality and performance – are supportive of the creation of *experiential value*. They facilitate the grand tour experiences over long distances, creating a rush of adrenaline and explorative experiences. Through such journeys, the brand also becomes a symbol of a certain lifestyle, contributing to the *symbolic value.* However, the balance between *symbolic and functional value* can become tricky especially if functionality depends on the use of technology. The *symbolic value* of some well-known brands has roots in heritage, craftsmanship, and use of certain materials - which can be in contrast or conflict with the use of novel technologies. That creates a challenge of integrating technology while preserving traditional forms and materials.

All values overlap at some point to create an overall luxury value, which is experienced on an individual level as well as being a social phenomenon that can be observed through the relationship between the *experiential* and *symbolic values*. *Symbolic value* is created socially, being what a luxury brand means to a community of people, whereas *experiential value* is individualistic and is the meaning of a brand or product to an individual person. These values also support each other, as in the example of a luxury car that offers both the *experiential value* through its craftsmanship, driving experience and the performance it offers, and *symbolic value* through becoming a member of a selected few people who own that car. Nevertheless, these values can also contradict from time to time as in the example of fashion elements. Some iconic shoes or dresses designed for certain events pose low *functional and experiential value* in terms of their uncomfortable design but create high *symbolic value* through their iconic, extraordinary forms, materials and designer or brands.

Taken together, the four types of value present a variety of clues and guidelines for designing luxurious experiences, however their focus is wide and extensive and depends mostly on branding strategies. In the following section, we will narrow-down the focus to understand how luxury user experience is created within the automotive industry.

2.4 Luxury User Experience in an Automotive Context

It is not surprising to see that the luxury products, which are remembered the most, are generally associated with self-representation such as accessories (watches, handbags jewellery etc.), fashion, cosmetics, and fragrances and also about experiences such as hotels and holidays (Yeoman & McMahon-Beattie, 2011). Cars are always perceived as a partner, a companion of their owners, as "noble descendants of horse-drawn carriages or coaches" (Kapferer & Bastien, 2009). The origin of the car can be traced to the 18th century but with respect to today's modern cars, the patent of Benz Motor Car (1885) is described as the "birth certificate of the automobile" (Daimler, 2018). For early automobiles, the main concern was a technical challenge to produce sufficient power from the motor – not aesthetics or human factors. Those early automobiles were the successors of the horse-drawn carriages, where the focus continued to be on the comfort of the passenger, as the owner of the car, instead of that of the driver or chauffeur. However, within the last century, the focus changed its orientation, with the owners of cars starting to be served and considered as part of the enjoyable driving experience. This change in focus transformed car design into an interdisciplinary and complex area of research.

The first car that was mass-produced and available to a wide audience was the Ford Model T (1914). However, during the 1920s – 30s, the Model T was followed by cars such as the Delage and Duesenberg, which brought a sense of luxury to the sector (Adler, 2000). These cars were produced in small numbers and the exceptional craftsmanship and attention to detail differentiated them from mass-produced examples (Warren, 2015). In time, wealthy people's concerns and desire for luxury became acknowledged through the emergence of a luxury segment for the automotive industry. Experience-based and heritage-based luxury car brands started to build and attract their own audience. Today, the luxury automotive sector shares similar strategies with other luxury sectors (see section 2.1 - The Concept of Luxury) for creating luxury value. The luxury value creation process for the automotive industry is discussed through examples in the following sections.

2.4.1 Creating Functional Value in Automotive Industry

The functional value of luxury products is summarised as "it completely meets my needs, and even exceeds them" by Kapferer and Bastien (2009). The functional value of cars is mainly set through high-quality durable materials, superior mechanical details and performance. However, the uniqueness of luxury cars is achieved by their incomparability (Kapferer & Bastien, 2009). The basic function of cars can be identified as mobility, but all luxury car brands have their own position with regard to this mobility definition. For example, Rolls Royce offers "an apogee of functional pleasure" (Kapferer & Bastien, 2009). Henry Royce designed the first Rolls‑Royce, thinking about "the best motor car in the world regardless of cost" (Rolls Royce Motor Cars, 2015). Bentley's 2015 Bentayga SUV (Sport Utility Vehicle) was released as the "world's fastest SUV" (Bentley Motors, 2015). Aston Martin describes their cars as "ever faster, more powerful, thrilling, comfortable – more beautiful – than the previous" (Aston Martin, 2015). Ettore Bugatti's goals are transferred into a car design that is "light, powerful and nimble" (Bugatti, 2018). We can discuss many other luxury brands verbalising their values with different words. Even though they all emphasize performance of the car, each differentiates itself from others by specific terms such as the 'fastest' for Bentley, the 'best' for Rolls Royce or 'nimble' for Bugatti. This variation makes it clear that there is not just one formula for functional value to be built into a luxury car.

Kapferer & Bastien (2009) argue about how uncomfortable it is to master a Ferrari – described as a car with its own fragilities and unique character. It is also observable in many sports cars (especially in BMWs) (Kapferer & Bastien, 2009) that the legroom and comfortable seating for passengers is overlooked in their design. Porsche presents another point of view, defining the driving experience in its Boxster model (Porsche, 2015) within a racing concept, by taking out every "distraction" such as air conditioning, radio etc. and making the car as light as possible to achieve a sports-type racing car. What we learn from this is that creating functional value in terms of performance might result in sacrifices to the comfort of the cars, but a unique and rewarding driving experience is provided in return.

Regarding the functional value of luxury cars, the performance or superior quality are not the only relevant variables. Certainly, there is not a standard that every luxury brand seeks to achieve. The standards, the objectives to achieve, or even the limitations are set by the companies themselves. Kapferer & Bastien (2009) summarises this as "the creator who defines the criteria": companies setting their own targets and specifying exclusive materials, mechanisms, design and production details etc. for reaching those targets. In summary, the definition of functional value changes from one luxury brand to another. However, an important observation is that the "bare necessities" of functionality is not enough to create desirability for luxury cars (Loureiro & Kaufmann, 2016). The cars also need to provide high symbolic and experiential value to achieve desirability.

2.4.2 Creating Symbolic Value in Automotive Industry

Vigneron's and Johnson's (2004) study showed that objects chosen to be purchased are an extension of people's own definitions of themselves. Consumption of luxury products is not only a self-centred process, but it also involves a comparison of oneself to others in society. Defining their identity through society, people have references from their surroundings, become influenced, attracted or even sometimes dictated by society. The objects that people possess, buy, or use, are part of their identity and therefore part of the story of social acceptance. While trying to distinguish themselves from a group of people by differentiating their consumption habits, people inevitably become aligned to an alternative (in their eyes, preferable) group of people.

Setting up a luxury image for a product and its associations is about building icons through time that are easily recognisable by society. As described earlier, the main concern for the earliest cars was not the aesthetics or human factors but the performance and power of the car. However, after several years the visual language that luxury brands created separated their cars from the products of other manufacturers and built-up exclusivity. One element of this visual language is the 'silhouette', exemplified in Figure 8 for the Porsche 911, for which designers have made minor changes through the generations but retained the essence of the vehicle. Even after half a century, the iconic silhouette remains the same and the car is identifiable through this appearance.

Figure 8. Porsche 911 generations

Porsche explains its general visual language design as follows (Porsche, 2018).

> *"A Porsche is immediately recognisable. This is thanks to the distinctive design idiom and contours: the roofline, the wings which are higher than the bonnet, the powerful shoulders. Features that every Porsche model has picked up on and reinterpreted for its own era and character – for more than 60 years."*

Another iconic feature of luxury car that is preserved through minor changes over the generations is the front face appearance. The front grille of luxury cars is used as a brand symbol and generally is subject to small design iterations to again keep the essence of an established visual language. This is exemplified by the BMW front grille evolution in Figure 9. The firm's 'kidney grille' is immediately identifiable as BMW, irrespective of the particular generation of car.

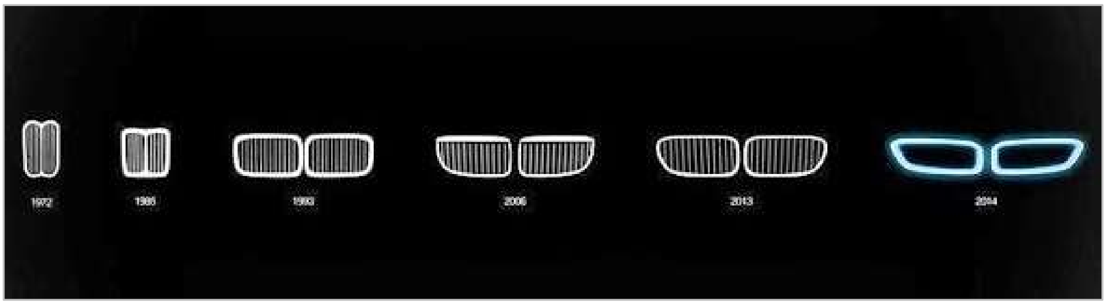

Figure 9. BMW kidney front grille through years

Most of the time, such silhouettes and car surface contours feature prominently in advertisement campaigns since they are symbols of the brands. These symbols, silhouettes, front grilles and characteristic lines are as identifiable as the brand's logo and name.

The icons of luxury car brands are set not only through visual language but also through sound, touch/haptic qualities and smell. The sound is a signifier of the car performance, which is another message that luxury car brands convey to owners. Cars are designed in harmony with their performance by making their visual appearance aggressive, strong, fast etc. But as a result of their high-powered engines, the sound of luxury cars also becomes an iconic element of their design. Kapferer & Bastien (2009) exemplifies this through the "fanatics of Ferrari", with laptops that start-up with the sound of a Ferrari engine. Even though the silence of a laptop is a signifier of high performance, the opening and closing sound mimicking a Ferrari engine gives a sense of Ferrari performance to the user.

If we are to discuss the senses of touch and smell in the context of luxury, materials become the focus of the discussion. Leather and wood, with their unique and natural characteristics, are the materials mainly used in luxury car interiors. The typical smell of leather is a research area for the automotive industry to maintain and enhance the sense of luxury for car interiors. Nagel (2016) emphasizes the power of smell and how it affects the decision-making process even in very low concentrations and how leather creates a sense of luxury through its distinctive smell.

Another dimension of symbolic value is the creation of symbols through the history, myths and heritage of brands. Luxury is highly associated with the history of a brand. In the car industry, although heritage can be seen as the combination of design elements such as silhouettes, front grilles, etc., it can also be reflected as the car experience and performance. Kapferer & Bastien (2009) mention the Rolls Royce as a "reincarnation of the gilded coach: nothing is too comfortable, sumptuous or beautiful for the king, for Queen Elizabeth II. The excess is in proportion to their symbolic rank, beyond the norm". The definition they provide shows how symbolic value is relational – and at the highest end is associated with all the luxuries of a royal lifestyle.

Heritage cannot be maintained just by stating, for example, "established in 1884". On its own, such statements are seen simply to reinforce that a particular brand is old (Kapferer & Bastien, 2009). The concept of heritage is about maintaining the myths and stories of a brand, focusing on the experience and challenges faced through decades, leading to excellence in production, design or any other feature. For example, a Rolls-Royce Phantom is produced in 2,600 hours: ten times longer than a typical Ford family car, signifying a considerable effort and time to create a very special car. Porsche defines its heritage as a principle "achieving maximum output from minimum input, a race-inspired philosophy" (Porsche, 2018) whereas

Bentley defines it as "being in a relentless pursuit of both luxury and performance" (Bentley Motors Ltd., 2015).

All luxury brands, especially those in the automotive industry, have their own stories to define their heritage and legacy – emphasizing on the beliefs, roots of their iconic design and experience through time, leading to excellence in production and quality. The design of luxury cars will continue to evolve taking into account definitions of heritage and craftsmanship, but technological advances and changing expectations of new generations of customer will drive luxury car manufacturers to be more critical about defining experience and technology in a way that resonates with their established symbolic values and heritage. The challenge implicit in this is a marriage between the old (heritage) and the new (technology).

2.4.3 Creating Experiential Value in Automotive Industry

As Milton Pedraza, an analyst from the Luxury Institute mentioned in his interview with Tamara Warren (an independent researcher), the concept of luxury over the generations has evolved from being something tangible towards being something experiential (Warren, 2015). He explains this through a survey carried out with Generation X, Generation Y and Boomers regarding luxury: "they all favour experiential goods more than tangible luxury goods". This change in focus is reflected by luxury car manufacturers, who in their websites highlight the driver and passenger 'experiences' of their cars. These experiences are often scenario-based stories focusing on particular trips, for example some related to discovering nature, challenging driving conditions, luxury holidays or attending prestigious events such as Formula 1 races. In these scenarios, manufacturers emphasize the driving experiences with their cars in different conditions. For example, Aston Martin in Iceland (Aston Martin, 2015) and Bentley touring amongst 'Oman's hidden treasures' (Bentley Motors Ltd., n.d.). Rolls Royce defines its driving experience as a 'magic carpet ride' unique to Rolls-Royce, integrating the newest technology suspension systems (Rolls Royce Motor Cars, 2015).

Luxury objects are perceived as objects of desire and passion, especially cars. Porsche defines itself as an attainable "dream" (Porsche, 2018). Even so, most luxury cars do not offer 'perfect' comfort or control, with smaller interiors, reduced legroom, and the constant sound of the engine performance etc. The point however is that they offer an unforgettable experience. Dream cars make people sacrifice comfort for the sake of the pleasure of driving such a car; they feel the handmade interior; they 'connect' to its designer, feeling the vehicle’s soul; they become a member of a ‘selected few’ with refined taste. Luxury car manufacturers create driving scenarios to stimulate people’s emotions and desires. These experiences make use of the unique properties of luxury cars to attract attention to the potential of achievable experiences.

In addition to these scenarios, the practical details of car interiors enhance the luxury experience through design, materials and realisation. Great attention to detail typically creates a luxury feeling, whilst materials such as leather can be mastered through the employment of craftsmanship. Lee (2015) defines the appeal of handmade objects with the phrase “human dimension”, which becomes embedded within the handmade object. Touching a handmade object or interior feels like touching the very producer of it. It is like a bond between the producer and the user. By interacting with these objects, the user has the chance to personally appreciate the “skill, time and care taken as well as the kinetic association” that went into the object’s creation (Lee, 2015).

The experience of luxury car interiors creates challenges for designers as well as opportunities. The functional aims, iconic aesthetics and multimodality require deeper understanding and analysis in every step of the design process, from conceptual form decisions to final material specifications. Each decision should be justified and create symbolic and experiential value for the driver’s or passengers’ senses. It is this complexity of luxury value creation and the links to practical design decision-making that are investigated through the fieldwork and main empirical studies of this thesis, reported in Chapters 4, 5, 6 and 7.

The literature review up to this point has explained the concept of luxury and user experience, followed by examples of luxury value creation through existing products. The examples revealed information about the reflection of these theories on ‘designing for luxury’ processes, however the core area of research is automotive HMI systems, which are also by definition complex. This following section examines automotive HMI, as the main subject of the research, to reach definitions, review areas of interaction, contrast new studies, and reveal trends and challenges for designing automotive HMI systems.

2.5 Automotive HMI

The Human Machine Interface (HMI) is defined as a hardware system that is supported to lesser or greater extents by software and associated electronic functionality. On a very broad level, users interact with a product through the HMI. HMI in an automotive context involves all the components that drivers/passengers interact with during their vehicle experiences. Automotive HMI is therefore complex, consisting of combinations of, for example, buttons, knobs, pedals, touch screens, pads, voice controls and even touch-free gestures. Such systems built with so many different elements to be integrated with each other requires thorough thinking and planning.

The definition of a 'car' has evolved over recent decades. Whereas once the car was viewed simply as a tool for travelling, now it is an integral part of our lives and creates a social environment for our mobility and independence (Kern & Schmidt, 2009). This transition has been highly facilitated by information technologies: as the information, sensing and functionality of the car have grown, so the car has become more intelligent and responsive. It is also becoming a social companion during driving, helping drivers in some tiring, boring or attention-demanding actions (e.g. adaptive cruise control, lane change assistant). Cars equipped with ever more interaction technology become increasingly influential on the overall driving experience.

The distribution of information and controls in cars is based mainly on driving-related activities and the safety of the driver and vehicle. Geiser (1985) classically classified driving into *primary tasks* (how to manoeuvre a car such as controlling the speed, checking distance with other cars (Kern & Schmidt, 2009), *secondary tasks* (that increase safety such as activating turning signals, windshield wipers (Tonnis, Broy, & Klinker, 2006) and *tertiary tasks* (related to entertainment and information systems), based on their relationship (proximity) to the principle goal of operating the vehicle. Inevitably these three task classifications have a hierarchy. For example, primary tasks require instant access since they are highly tied to safety and can cause fatal errors, whereas tertiary tasks are not urgent and result in lesser consequences such as annoyance and frustration. This hierarchy is reflected within the in-car environment, most notably the location of HMI elements related to the tasks. The HMI elements related to primary and secondary tasks are located closest to the driver (e.g. around the steering wheel) whereas HMI for tertiary tasks is generally located on the central stack (Kern & Schmidt, 2009; Tonnis, et al., 2006) (Figure 10). Whilst these general observations are still relevant, the introduction of new interactive technologies is starting to challenge and raise questions about the ideal location of HMI elements and their relation to driving tasks. Feld & Endres (2010) claim that vehicle HMI is currently facing an evolutionary change. Research in the area has generally focused on the *primary tasks*. However, with the advancing technologies, there are possibilities to make use of intelligent user interfaces and create context-aware systems that sense factors affecting the driver or passenger experience, and even act in response appropriately.

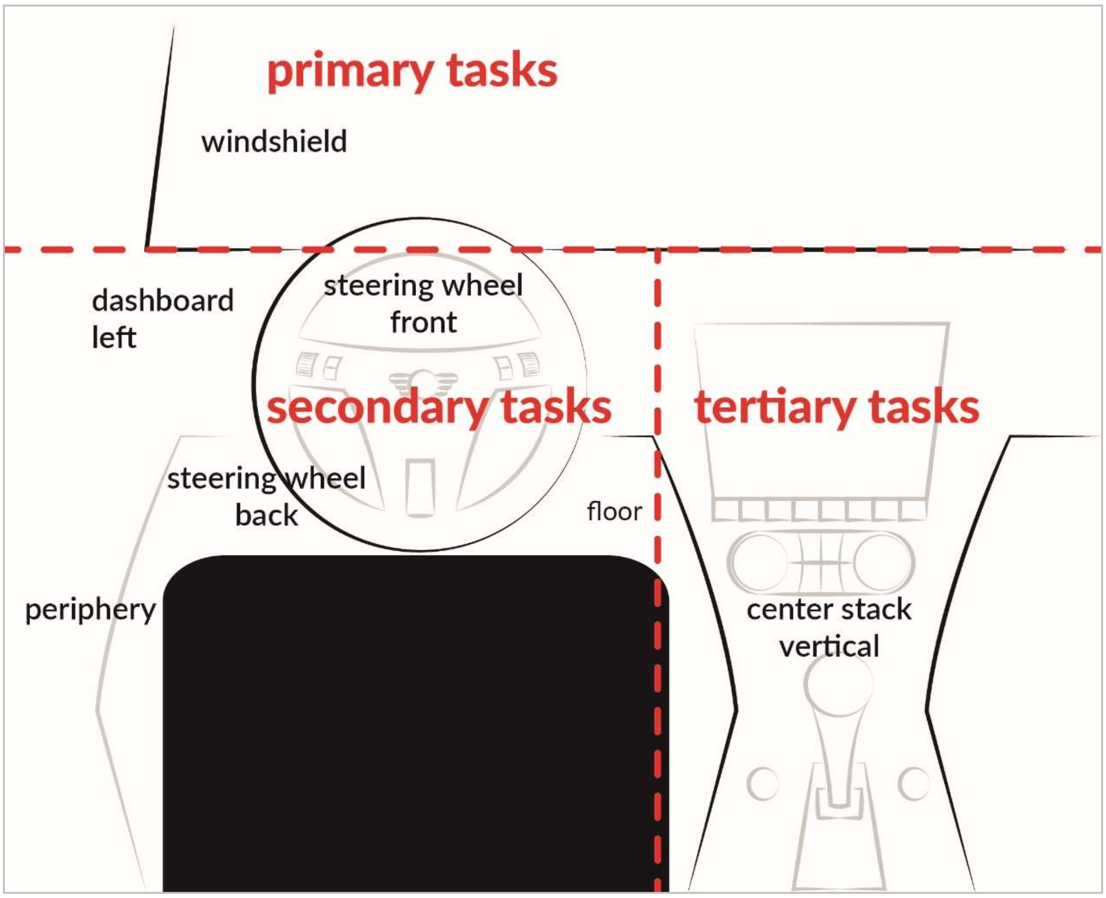

Figure 10. Division of driver's interaction environment (adapted from Kern & Schmidt, 2009; Tonnis et al., 2006). (The black rectangle indicates the driver's seat)

Driver assistance systems allow drivers to divert some of their attention away from primary and secondary tasks and onto tertiary tasks (e.g. music, communication) that enrich the driving experience. Within the car interior and dashboard, these technological-driven changes can be seen to bring infotainment-related HMI elements closer to the driver.

The driver dashboard and related area is one of the most evolving areas in automotive design. Since by definition the driver is in control, most of the information and driving-related controls are required to be located within the driver's immediate (non-extended) reach. However, the information (feedback, feedforward) that is presented to the driver – whether statutory or optional – is becoming voluminous and potentially denser as each car generation is created (Gkouskos, Normark, & Lundgren, 2014), as shown in Figure 11. To deal with this, technological advances have made it possible to present a certain amount of information in a limited area or convey information using senses other than visual.

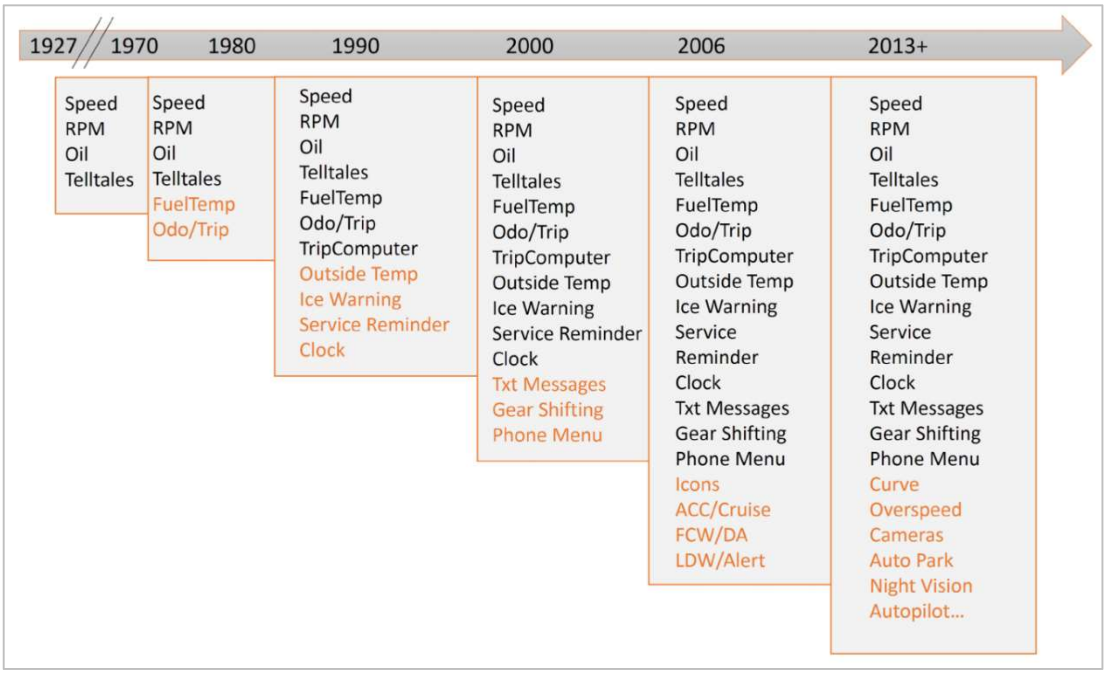

Figure 11. The increase of driver information (Gkouskos et al., 2014)

Interactive technologies have not only brought the advantage of providing information but also have changed ways of reaching and browsing through this information. Interaction technologies, offering multimodal experiences, create a variety of opportunities for information provision to the driver not in demand for visual attention. Therefore, it is possible to see the impact of technological advancements on design and interaction within car HMI systems. Hess, Gross, Maier, Orfgen & Meixner (2012) identify the essential components of HMI systems as: input interfaces (e.g., multi-function button), output interfaces (e.g., screen, speaker), or both Input-Output interfaces (e.g. touch screen). The following section reviews studies regarding those interactive technologies and their impact on the driving experience.

2.5.1 Impact of Interaction Technologies on Automotive HMI and Driving Experiences

With technological developments, driver information has inevitably increased, with systems becoming increasingly complicated. One of the dominating elements of a modern (2019) car dashboard is the ubiquitous touch screen, which offers relatively large areas of full-colour and high-resolution information display, but is not always easy to interact with, especially in driving context. In our daily lives outside the context of driving, while using these screens on tablets and mobile phones we can direct our full visual attention in order to locate icons, scroll bars, tabs and many other ways of accessing and manipulating information. However, for obvious reasons, it is not possible for the driver to pay so much attention to the screen: the driver typically takes a glance at the screen for less than a second and then quickly reverts to the primary driving task of keeping his/her eyes on the road for the rest of the time (Rümelin & Butz, 2013). In some commercial car models (e.g. BMW iDrive in Figure 12) this issue is addressed through the use of a multifunctional knob (acting as a knob, toggle switch, button or even touchpad), which offers an indirect interaction with touch screens. Such multifunctional knobs are complex by their nature and require a learning process for users. The communication of this multifunctionality through design, and the learning process they require, pose some challenges such as misunderstandings or mis-remembering during interaction.

Figure 12. BMW iDrive multi-functional knob (Telematicsnews, 2012)

Compared to predecessor display solutions such as more basic LCD panels or backlit fixed icons, touch screens have much wider scope for information presentation, but nevertheless the amount of information relevant to automotive HMI is constantly growing. Even browsing through a music list and setting a comfortable listening volume typically requires several layers of information, button presses, icon activations and other actions. The study of Kujala (2013) evaluated the actions of button clicks (on screen), swipe (page-by-page) and the kinetic menu structure in touch screens. On-screen buttons and kinetic menu organisation demand constant visual attention to achieve accuracy, whereas swipe actions require less visual attention and are easier to interact with compared with other options. The advantage of using physical buttons is the tactile and haptic feedback they offer instantly during interaction, providing a physical grounding for the point of interaction, whereas touch screens often require a secondary glance for confirmation. Pitts, Burnett, Lee, Wellings, Attridge & Williams (2012) directed their studies to enhance touch screens with haptic feedback in a driving context to overcome this visual demand. Adding haptic feedback resulted in a decrease in a secondary glance (a glance made after the activation of a task or function), thereby allowing the driver to be more concentrated on driving activities. In addition to these, there are also studies comparing different types of touch screens (resistive, capacitive and infra-red) in a driving context (Pitts, Skrypchuk, Attridge & Williams, 2014), alternative means of text input to touch screens during driving (Wilfinger, Murer & Tscheligi, 2012), and use of multiple fingers while interacting with a touch screen in a driving context (Colley, Väyrynen & Häkkilä, 2015). These studies show that the touch screen – as the dominating element of the automotive interior – still presents challenges and opportunities for research in order to achieve experiential improvements.

In response to criticisms that touch screens require continual visual demand, research has focused on finding other means of input to HMI systems, such as audio or gestural interaction. Gestures and audio commands pose the potential for decreasing visual overload on the driver. However, Pfleging, Schneegass & Schmidt (2012) concluded that even though they decrease visual demand, the interaction process with these alternative technologies is slower compared to physical controls. Another challenge for audio commands is the noise level in driving contexts (driver listening to music, chatting with friends or stuck in dense traffic in urban environments), which interrupts sensors and as a result, the flow of interaction. Sezgin, Robinson & Davies (2009) addressed this problem by combining other indicators such as facial gestures with audio commands to overcome input ambiguities and to achieve precision in audio command technology.

Audio commands and gestural interaction can cause a dramatic change in automotive interiors by replacing physical controls with sensors embedded (seemingly invisibly) in the interior. However, regarding the muscle memory and habits of drivers, along with a lack of user research data in simulated or real-life driving conditions, these interaction technologies still require further investigation before their effectiveness can be established. For example, Riener, Ferscha, Bachmair, Hagmüller, Pühringer, Rogner, Tappe & Weger's (2013) study was directed to find a suitable area of gestural interaction in a car. Limiting users' attention on the central console, the researchers asked their experiment participants to show where they would like to carry out particular gestures to achieve pre-defined tasks. The general outcome showed a tendency to use gestures closer to the steering wheel, keeping hands close to the critical controls necessary for driving. Another concern about gestural interaction is that the gestures rely on a vocabulary of movements that are novel, and therefore demand a phase of learning. To address this problem, Loehmann, Knobel, Lamara & Butz (2013) tried to find gestures that are culturally independent - used in everyday communication in different cultures – such as a ‘stop’ gesture. The use of a ‘stop’ gesture to turn off some activities (e.g. radio) is reported to be easier to use and experientially more attractive than using a physical control.

With its potential to lessen the visual load of the driver, in-car gestures are still under much debate regarding the type of gesture (e.g. air, device-based), position of the interactive area (Riener, et al., 2013), difficulty in standardisation (e.g. cultural differences) (Stern, Wachs & Edan, 2008; Urakami, 2014), and degrees of learning. May, Gable & Walker (2014) claim that using the central console as an area for air gestures causes an increase in drivers’ workload compared to direct touch interaction. However, the study of Döring, Kern, Marshall, Pfeiffer, Schöning, Gruhn & Schmid (2011), which took gestural interaction on a multi-touch steering wheel and compared it with the use of gestures on central console had different results than May et al. (2014): in the case of Döring et al. (2011), changing the area of interaction was found to result in a safer driving experience with fewer distractions.

Alternative input technologies can provide solutions for visual overload. Additionally, smart technologies are a promising avenue to reduce this overload. Some strategies for coping with visual overload have been demonstrated by car manufacturers, such as making use of layers of information and the hierarchical ordering of information. However, with the complexity and huge amount of information, it has become more complicated for drivers to control and interact with their cars. For this reason, Giacomin, Robertson & Malizia (2014) questioned the naturalness of in-car interactions in the current era. They conducted several interviews with open-ended questions and devised a design checklist for the automotive industry. This checklist mainly consists of elements such as *sensing, being humanlike* and *co-piloting*, which are concepts that are highly related to the ‘smartness’ of a car. In order to reduce the number and complexity of controls in the car, making the car smarter - that is, for it to understand and even to act in harmony with the events around its use – is another way to create an antidote to visual information overload. However, for achieving this smartness, it is important to keep it as subtle and simple as possible to avoid the feel of a car patronising its user. Another solution to this information complexity is to make the HMI system as adaptable as possible. With emerging technologies, it is possible for products to understand, estimate, and even sometimes anticipate and act in relation to the context in which the product ‘finds itself’. We experience the concept of adaptability with some of the personal devices that try to adapt their menu system according to our preferences. Davidsson & Alm (2014) revealed the fact that it is desirable for drivers to have adaptable systems, especially to different driving contexts (e.g. when parking, when navigating highway intersections, or slowly progressing in queueing traffic). Although there are overlapping preferences of drivers about information presentation in different situations, there are also differences in when and how to have this information, which requires further research.

Another facet of interaction is information presentation. The studies on information presentation range from visual presentation (i.e. display types, graphical representation) to other modalities such as the use of audio or haptic feedback. Visual information presentation is typically centralised on the screen, with alternative screen technologies discussed in terms of technical feasibility and location within the car. 3D stereoscopic displays are visually attractive and fascinating in terms of novelty, offering a prioritisation of information through layers (Broy, Alt, Schneegass & Pfleging, 2014). Even though the clear representation of information layers is desirable, the 3D effect can cause headaches and dizziness in a driving context (Broy et al., 2014). Head up displays (HUDs) are another fascinating display technology that offers drivers the possibility to keep their eyes up on the road and concentrate on driving whilst simultaneously accessing and processing visual information. The study of Pfannmüllera, Kramer, Senner & Bengler (2015) discusses how to present navigation-related information on HUDs. Combining HUDs with augmented reality enhances attractiveness and usability. The combination provides the opportunity of mapping relevant information on the road in 3D, instead of 2D information which may become ambiguous or disconnected in certain contexts. HUD technology can be stretched to cover an entire windscreen (through the use of projection), surrounding the driver with information. The study of Häuslschmid, Osterwald & Lang (2015) comparing HUDs (head up displays) with WSDs (windshield displays) determined good ratings for WSDs, since participants defined the WSDs as clearly structured, presentable and innovative. Reflection of information on the windscreen is perceived as desirable and safer in terms of keeping drivers' heads up and eyes on the road. However, WSDs are also debated to have a potential risk of occluding objects on the road (Pauzie, 2015), leading to safety problems and discussions. In addition to the underlying display technologies, the content and organisation of screen-based information are also effective in and influential on the driving experience. The study of Kujala & Salvucci (2015) revealed that a larger number of items presented on a screen results in an increased glancing time by the driver. Ecker, Broy, Hertzschuch & Butz (2010) offer the solution to reduce glance duration by adding pie menus to the menu structure of touch screens. The study shows that adding sub menus, supported by visual elements (changes in colour, shape, size) have the potential to lessen the glance duration.

Even though the main focus regarding information provision is on the visualisation of information (not the content of information), there are other ways of providing information to the driver. As the visual workload of the driver is getting heavier, research focuses on information provision through different modalities or multi-modal solutions. In the study of Kern, Marshall, Hornecker, Rogers & Schmidt (2009) a multi-modal navigation system was investigated. A navigation system is a frequently used element of a visual-based HMI but problematic not only because of its visual demand but also because of audio feedforward and feedback (e.g. instructions, observations) interrupting the driving experience taking place outside of navigation (e.g. talking, listening to music). Kern et al. (2009) studied ways of presenting navigational information to drivers making use of audio, visual and vibrotactile feedback combined as pairs. Enhancing visual navigational information with haptic and audio feedback resulted in increased driving performance and less annoyance. Jeon (2014) named the audio feedback as “sonification” of car interaction and offered information (parameters about fuel efficiency) to the driver through speech and pre-defined sounds. As expected, the use of speech-based warnings caused annoyance, but solution using sounds instead of speech were evaluated as promising.

The variety of technologies relevant to automotive HMI can be overwhelming when evaluated in terms of their possibility for shaping in-car interactions. Even though novel technologies offer many desirable interaction scenarios that enhance the driving experience, they also pose safety challenges. Technology integration in a driving context requires thorough research and analysis not only in terms of safety but also enriching the driving experience. By narrowing-down our focus on luxury car interiors in the following section, the challenges and opportunities of technology integration in a luxury driving context will be discussed.

2.6 Challenges and Opportunities for Luxury Automotive HMI

Automotive HMI with its complexity and diversity of components poses several challenges and possibilities for design decisions. Reflecting the idiosyncratic character of luxury experience on automotive HMI is even more challenging, regarding the creation or realization of luxury values through design decisions. Descriptors of luxury experience (from interactions) are vague and undefined and generally based on designers’ intuitions. As aforementioned, luxury is extensively studied in marketing and psychology literature but not in relation to design details and product qualities. But design details and product qualities create the main focus for designers in the luxury automotive sector, accompanied by additional challenges of staying up-to-date, integrating technology, and maintaining the heritage, tradition and expertise of craftsmanship.

Luxury automobiles are exceptional in terms of their performance and technical superiority, since their core values are built on these attributes. However, the reflection of this technical superiority to car interiors is still a question-mark when evaluated with regards to aesthetics of interaction and resultant user experiences. Luxury brands face the challenge of aligning their technical superiority with contemporary customer profiles, based on trends and integration of up-to-date technologies in their cars. Evaluating the effects of new technologies on car performance is possible in lab environments, on a quantitative basis, in the absence of user testing. On the other hand, user experience evaluation of HMI requires the participation of users (drivers) and can result in large quantities of qualitative data that take substantial time to analyse. In addition to the time and effort required for research and development, the introduction of new technologies always poses a risk for breaking the tradition of excellence in luxury. Therefore, luxury car producers do not have a chance to make a mistake in their cars to keep their reputation and brand loyalty of customers.

In addition to the risk of introducing new technology, another challenge for automotive HMI is the integration of the various components that usually make-up an HMI system. Gáspár (2013) explains that integration is an especially challenging aspect of HMI design, since conventionally most of a vehicle's functions are controlled, designed and manufactured separately by suppliers and vehicle companies. This presents communication problems and conflicts among the assembled HMI components, which have conventionally been designed to act very well independently but not necessarily so well as a whole system. In addition to these technical problems, there are also design-based concerns in terms of placing these components within a complete dashboard. All technologies and components are made up of different materials and shaped in different forms. The excellence that luxury offers in terms of precision is at risk of being jeopardised through the use of a variety of components from different producers.

As mentioned, luxury is created through consistency and tradition across many years. This creates a challenge when contemplating the use of novelties and new interaction technologies in luxury cars. Consistency in the car industry is maintained through locations, sizes and design decisions regarding the most crucial controls (such as gear sticks, pedals, steering wheel, hazard warning lights). This consistency leads to a muscle memory for users.

However, technologies can challenge the appropriateness of the locations, sizes and designs of controls through offering a range of new possibilities, as well as bringing new constraints. Radical changes within luxury products can break the flowing experience (that users have internalised over years) and can risk customer loyalty that has been based on familiarity with certain actions and in certain use scenarios. The physical embodiment of technology also contradicts with the heritage and craftsmanship not only in terms of manufacturing volume but also the use of materials. For example, the appearance of a faultless, flowing wooden dashboard underlines a brand’s expertise, but placing alongside it a touch screen with a flat surface and a plastic/metal bezel risks undermining the whole visual coherence of the HMI system. Many of the components associated with innovative interaction technologies are miniaturised, requiring the precision of mass production and use of certain materials to achieve their functions. On the other hand, through the use of heritage elements, expertise and craftsmanship, brands offer the ‘human touch’, ‘the soul of the craftsman’ through their luxury products. Technological components often consist of easy-to-shape, conductive or insulating parts made of plastics or glass as a result their visual appearance (especially when turned off) is very similar regardless of price or quality. From this perspective, although touch screens can look similar in terms of appearance, we can speculate that it is the screen resolution, responsiveness and the design of graphics that may lead to a luxury interactive experience. The perception of luxury comes with the usage to these kinds of components, not the appraisal made at first sight, smell or touch as has conventionally been the case when interacting with a leather seat or steering wheel.

To sum-up, the luxury automotive sector faces several challenges regarding the use of new interaction technologies, however these challenges can be interpreted positively as a chance to set-up a luxury ‘heritage of technology use’. This will require diverting focus on the concept of luxury towards its realization through interactive elements, integration of technologies, and the reflection of brand values through technology use. The use of premium materials alongside exquisite craftsmanship is a dominant route for creating luxury value for automobile brands, however in an ever increasingly digital and information-driven world, this traditional route is not sufficient. As luxury automotive manufacturers lead the way for offering performance-related technologies to the user, they must also now reflect their expertise on in-car technologies and define desirable luxury interactions and experiences that complement and expand their brand identity.

CHAPTER 3

METHODOLOGY

This chapter focuses on the methodology used to decide on which studies would be carried out during the PhD research and why. The research was planned to contribute to design research methodology and design for automotive experiences. Because of the multifaceted nature of the research, a requirement was to plan successive work packages to understand luxury, designing for luxury driving experiences, and offer insights to relevant stakeholders. For this reason, five work packages (WPs) were proposed, each focusing on different aspects of the research.

- WP1. Work package 1 focused primarily on building up an understanding of the research area and keeping up-to-date with concepts, terms and findings of research studies related to the PhD. This work package involved literature reviews and expert opinions through meetings with collaborating bodies.
- WP2. Work package 2 was about understanding the foundations of luxurious automotive HMI through benchmarking of existing luxury automobile controls and interactions. This work package was carried out in collaboration with Bentley Motors Ltd., who specified the competitor brands and provided the necessary fieldwork setting.
- WP3. Work package 3 was designed to reveal descriptors of luxury from the users' perspective. This core study of the PhD consisted of a series of 28 interviews to understand design features creating a perception of luxury on users. The process started with interviews with Bentley staff based on their experiences with their cars and practical experiences within the luxury sector. The interviews were recorded as videos and followed by detailed transcriptions (including physical actions and areas of the car that participants interacted with). All the transcriptions were taken through a thorough qualitative analysis process to reveal design features communicating (or potentially communicating) luxury, as well as connections between those features.
- WP4. Work package 4 was built upon the information gathered and analysed in WP3, leading to luxury descriptors for automotive HMI, a map of luxury experiences, design directions and example design concepts as an inspiration source. The whole PhD study was informed by a 'research into design' and 'research for design' approach; within WP4 the researcher created design proposals in the light of the gathered data.

- WP5. Work package 5 involved the process of exploring technologies that can be used to simulate HMI in digital virtual environments, as a means to extend Bentley Motors' capability into virtual prototyping for interaction scenarios and solutions. This work package was carried out in collaboration with the VEC, consisting of a workshop and a series of meetings for expert opinion.

The details of the work packages 1-5 are explained in detail in the following sections. The work packages followed a generally linear flow when put into practice during the conduct of the PhD research, with a few exceptions as summarised in Figure 13.

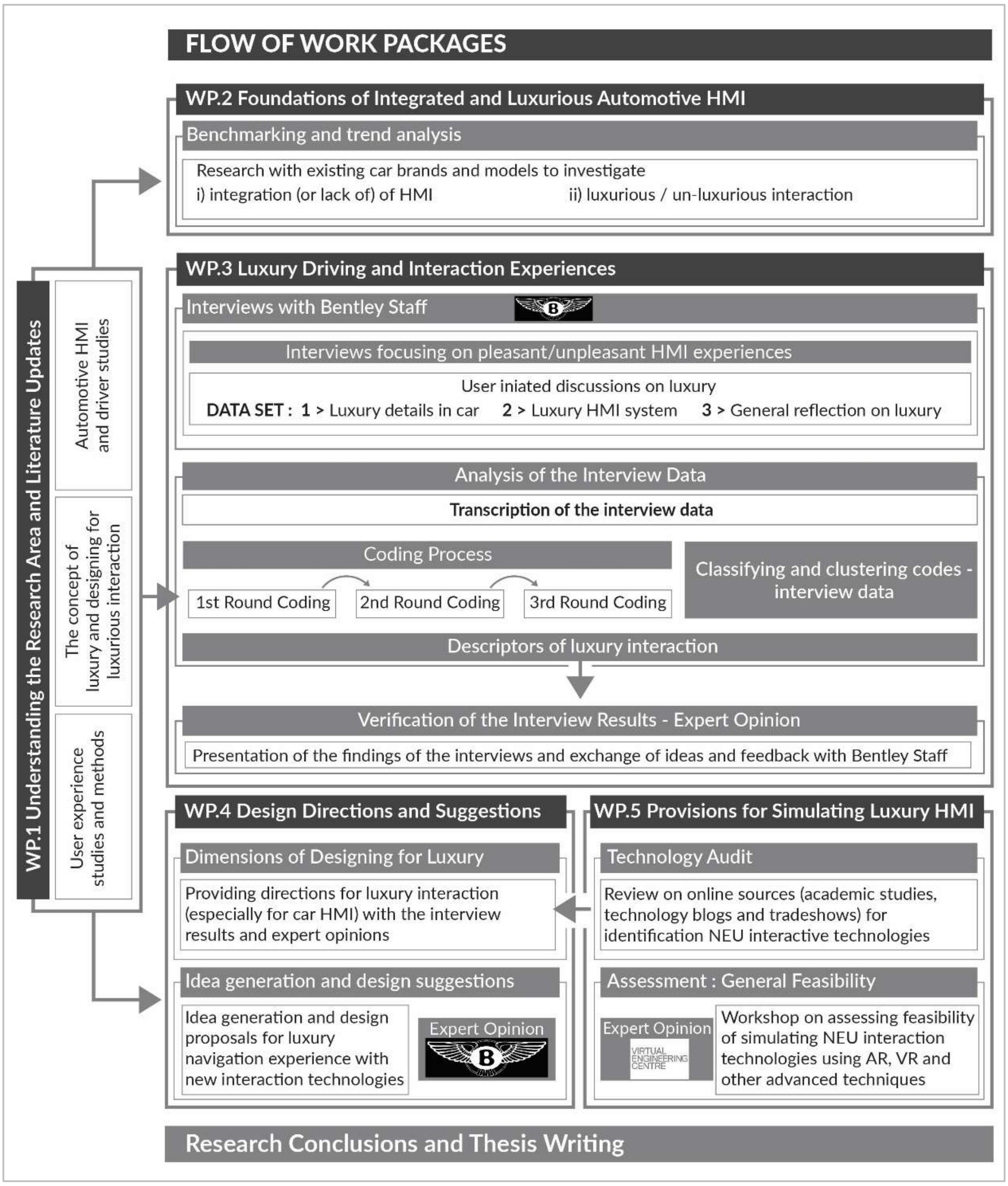

Figure 13. The Flow of Work Packages

3.1 Work Package 1: Understanding the Research Area and Literature Updates

This work package was devised as an umbrella for the subsequent work packages, feeding into each of the studies carried out. Each study had its own characteristics and literature, so their review was an ongoing process tied to other studies. The main body of literature relevant to the PhD research has been structured as a literature review in Chapter 2: Literature Review, which explains previous research within the areas of the Concept of Luxury, User Experience (UX), Luxury UX in an Automotive Context and Automotive HMI.

The first stage of the literature review was directed towards understanding the concept of luxury. This path of investigation revealed gaps and opportunities for studying luxury from the point of view of user experience. The review on luxury commenced with the origins of luxury throughout history, since the definitions and understanding of luxury have changed with historical events and social changes. The history is followed by the unique qualities of luxury products and experiences and understanding what makes them luxury from branding and personal perspectives, bringing together studies by Dubois et al. (2001), Featherstone (2014), Kapferer and Bastien (2009), Kapferer (2012), Mehta (2014), and Turunen (2017). The term 'consumer' instead of 'user' is used frequently in this section of the literature review, as the main literature originates from branding and marketing fields where product evaluation is made from a purchaser/consumer point of view. Even though the literature originates heavily from marketing studies, it contains cues and clues for designing for luxury. The last stages of the luxury literature review targeted the extraction of design possibilities from the marketing literature and defined several luxury values for products and their ownership/use. Overall, the literature review reciprocates between fundamental studies in UX and luxury and their application or exemplification in the automotive industry, by using commercial examples as an illustration for the points raised.

The literature review on UX was aimed at understanding the fundamentals of UX from different perspectives. The subject was crucial for the research since one of the aims of the PhD was to understand luxury UX through in-car interaction. For this reason, the initial step for the literature was to define and deeply understand UX studies. Several studies define the fundamentals of UX, such as Jordan (2000), Norman (2004), Desmet and Hekkert (2007), Karapanos, et al. (2009), Hassenzahl (2010), Roto et al. (2011), von Saucken, Michailidou & Lindemann (2013), von Saucken and Gomez (2014). All these studies share similar concepts, involving a definition of UX that starts with sensorial stimulation and perception of the user, assigning meanings to stimuli and the affective responses (aesthetic, emotional) that can arise. The literature in UX reveals that understanding UX is not only related with the product itself but also the context, which is explained through four factors (technical, personal, social, environmental) in the white paper of Roto et al. (2011). These factors condition the feelings, associations and interpretations of products.

The context of the PhD research is driving experience; therefore, it was crucial to understand the factors and components of driving experience. The review revealed factors ranging from the social environment within the car (passengers, communication technologies), environmental factors reflecting on the driving experience (such as weather, road conditions) through to technical advancements and feasibility studies on automotive HMI. It was also crucial to understand the methods used in previous work to research the use and specification of automotive HMI (with regards to feasibility, suitability, and adoption in certain scenarios). Accordingly, the literature review on automotive HMI includes studies focusing on: different factors influencing driving experience, such as secondary driving tasks (Galarza, Bayona & Paradells, 2017), traffic complexity and density (Teh, Jamson, Carsten & Jamson, 2014), adverse weather conditions (Qiu & Nixon, 2008), driver stress under different road, weather and traffic conditions (Hill & Boyle, 2007; Kilpeläinen & Summala, 2007); new technologies shaping in-car interactions such as browsing information (Kujala, 2013) and haptic feedback (Pitts et al., 2012) on touch screens, the effects of screen size on driving (Rümelin & Butz, 2013), the effects of new interactive technologies and products on driving (Schmidt et al., 2010), use of 3D displays as instrument cluster (Broy et al., 2014), use of head up displays for navigation (Pfannmüllera et al., 2015); and methods (especially simulation technologies) for understanding user in-car interaction contexts (Tideman, Voort & Houten, 2008; Kern et al., 2009; Moehring & Froehlich, 2005).

3.2 Work Package 2: Foundations of Luxurious Automotive HMI

The literature review revealed the fact that luxury has not been studied deeply in relation to product design details and especially people's interaction with luxury products (see 2.3.3 - Product Experience and Luxury Values). Most of the published works relating to these points stem from marketing research that is focused on brand qualities and the creation of luxury values through design, but not on the details of designing for luxury experience and how such experiences may be encouraged through the physical and digital realization of product designs. Designing for luxury experiences with products generally, and with automotive HMI specifically, was therefore identified as an area in which further research would be beneficial. The general population can to some extent define the concept of luxury experience from their own perspective, whether experienced first-hand or imagined. One of the founding skills and responsibilities of designers is to empathise with users in different contexts and to understand the differences in people's expectations, concepts and definitions. Empathy is most easily achieved if the designer has personal experiences of the product sector, problem area or opportunity under scrutiny prior to undertaking detailed user research. For the present research, although the researcher had been acquainted with various luxury goods, the specific area of luxury automobiles was a new area of understanding. Since luxury products are not widely available for 'trying out' and their design is not associated with a checklist of principles or measurable properties, it was necessary for the researcher to carry out orientation studies to become familiar with the luxury automotive sector. Initially this was achieved through visits and discussions with Bentley Motors staff, interacting with their cars. This provided a baseline understanding of the sector.

A follow-up study was then made to gain exposure to other luxury car brands and to generate initial results on the similarities between car models for realizing luxury HMI, based on a benchmarking approach. Considering the availability of luxury cars and confidentiality arrangements with Bentley Motors, the follow-up study was designed as a practical evaluation session where the researcher made first-hand interaction with, and evaluation of, luxury car interiors to extract general findings on luxury details by interacting with the car HMI (4.1 - Orientation Study - Benchmarking and Trend Analysis). Jordan (2000) defines this method as 'immersion' and describes it as a process of experiencing a product and taking notes and understanding the user experience. He uses the term "pleasurability" as the evaluation metric, but for the purposes of this research the term "luxuriousness" was more appropriate. The advantage of using the immersion method was that it did not require the collaboration of additional participants, which was important on two counts at the early stages of the research: firstly, preserving confidentiality, and secondly maintaining spontaneity of the study as an orientation exercise.

For the study, Bentley Motors arranged the availability of competing brand cars for benchmarking (Audi TT, Mercedes AMG GLE, BMW X6 M) as well as their own product (Bentley GT). Such an assembly of cars for side-by-side evaluation would have been extremely difficult without the company’s assistance; the choice of competing brands and models was determined by what was available on-site at the company’s Crewe headquarters. As a summary of the benchmarking process, grayscale or inverted images of the car interiors were created to impose a uniformity of colour between models (Figure 14). The images were printed onto A4 papers and used as a canvas onto which notes from the benchmarking session were made. Additional notes were made in a notebook, highlighting the exact areas and controls within the car interior and HMI. The benchmarking process was also recorded through photographs and videos.

Figure 14. Grayscale/Inverted car interiors

The immersion method resulted in a combination of factual observations and personal UX statements. The data (images, videos, notebook, marked-up printouts) were analysed on an individual car model basis, followed by cross comparisons. The analysis of the data revealed in-car interaction trends and luxury cues and details used in current commercial cars. It also provided a personal understanding of luxurious car experiences, vital as a foundation for the subsequent phases of the research.

3.3 Work Package 3: Luxury Driving and Interaction Experiences

Accompanying the variety of definitions and dimensions of UX located in the literature are several qualitative and quantitative research methods for capturing and analysing UX. This variety spans controlled laboratory studies to expert evaluations. The workshop carried out during the special session of CHI 2009 by Roto, Obrist & Väänänen (2009) was helpful in revealing the range of methods applicable to UX studies: (i) lab studies with individuals, (ii) lab studies with groups, (iii) field studies (short, e.g. observations), (iv) field studies (longitudinal), (v) surveys, (vi) expert evaluations, and (vii) mixed methods. Each method has advantages and disadvantages that depend on the aims and objectives of the specific studies being carried out.

As previously mentioned, no evaluation methods or checklists exist that provide design criteria for the evaluation of luxury products. The chosen method for the main study of this PhD research – an in-depth evaluation of in-car user experiences to inform luxury automotive HMI design - was therefore required to emphasize revealing such information. The main study was intended to be generative in nature, aiming to produce new knowledge on designing for luxury in-car experiences. For generative studies to build new theories without prejudice or bias towards existing theories, the common approach to use is 'Grounded Theory' introduced by Glaser and Strauss (1967). Grounded Theory starts with a research question/hypothesis, followed by the collection and analysis of qualitative data to answer, support or refute the question/hypothesis. Data are typically analysed through qualitative data analysis methods, seeking to identify patterns and overlapping concerns amongst the full dataset. To achieve this, the data examination process involves grouping and then clustering, using emergent codes, categories and concepts. Those codes, categories and concepts set the grounds for building new explanations (theory, models) from the data. In principle, the codes, categories and concepts often include some that are existing or well-known, but predefined interrelations or connections are avoided and left to the emergent analysis processes.

The chosen method of data collection for the main study was a field study involving in-car interviews with car drivers, with the data then analysed with a Grounded Theory approach. The main study sought to dissect users' evaluation criteria in terms of car interiors, their experiences with automotive HMI and their needs and desires related to these in a luxury context. Because UX is context-dependent (Roto et al. 2011), studies aiming to uncover aspects of UX are generally carried out in real-life conditions or by prototyping these conditions. For the present research, drivers' views and evaluations of detailed aspects of their car HMI were sought. This was predicted to require their concentration and attention, which ruled-out evaluations being made during driving on the basis of safety concerns. Furthermore, the orientation studies revealed that the kinds of HMI evaluations that were sought did not require a driving context, either because the HMI features were not reliant on the car being driven or their evaluation could be made based on typified past experiences. With these justifications, the decision was made to interview participants in their own cars in a parked position, with their HMI system activated and ready to interact with.

In-car interaction is complex by its nature, including multiple steps with controls and interfaces, as well as multiple modalities of interaction ranging from the use of physical buttons to gestures. Additionally, in-car information provision consists of a variety of data (Gkouskos, Normark, & Lundgren, 2014) provided to the user through a variety of components ranging from displays to audio commands and feedback. Because of this complexity, it was considered unwise to interview drivers in an environment away from their car. Instead, the interviews were carried out in their own cars that they had driven to work on the day of their interview. This way, the aim was to stimulate fresh acquaintances as well as contextual memories in the environment specific to their personal experiences. In addition to such stimulation, the in-car interviews provided users with a chance to point-out exact areas of the automotive HMI that they referred to, and to re-enact the actions that they carry out to achieve certain tasks.

The in-car interviews were carried out with a semi-structured interviewing technique, consisting of open-ended questions to understand users' criteria and points of view when they are experiencing their own car interiors and HMI systems (mostly with premium brand cars) and transposing their thoughts in the context of luxury interaction. Participants were asked to talk about the details that they find to be 'luxury' in their car interiors and HMI systems (irrespective of whether their own car was a luxury brand), guided by questions that sought to reveal details of their experiences. The interviews were recorded as video, audio and (from time-to-time at especially 'revealing' moments) photographs, so as to capture the exact steps of interaction for certain tasks, and to pinpoint physical areas and components of the HMI that they interacted with at the time of interview. The researcher additionally took notes about the interview process and the general impression of the car and participant during and after the interviews.

The interviews were followed by transcriptions of the data, which involved replaying the video and audio recordings repeatedly. For the transcription process, the videos were quite helpful for pointing out which actions and product areas that users interacted with during their verbal (audio) evaluations. The transcribed data were transferred to Microsoft Excel spreadsheets to be coded, analysed and classified. For the analysis process, Grounded Theory (Glaser & Strauss, 1967) and Content Analysis (Krippendorff, 2004) were used. In combination, these data analysis methods are effective for reducing a large amount of data into discrete categories through iterative coding and pattern-seeking. To identify the categories and patterns, coding is carried out that requires meticulous investigation of the transcript data sentence-by-sentence. Coding is the process of assigning "a word or a short phrase" that captures the essence of language-based or visual data (Saldaña, 2009). The process for the PhD involved not only assigning codes to language-based data but understanding links and relationships between coded data. Practically, coding is an interpretive process requiring the researcher to make sense of data whilst being mindful about the codes already assigned to parts of the data. Therefore, it is a cyclic process that involves the researcher going through the full dataset multiple times (three-four times) to interpret, filter, highlight and re-code (Saldaña, 2009) until a consistency and uniformity in coding is reached. The process starts with open-coding, involving the assignment of descriptive codes from the text, and follows with interpretation and reconsideration of those codes having identified (or not) patterns such as similarities or differences amongst them. Researchers who carry out such coding are aware that there is not any single formula or sequence to follow during the coding process.

> *Patterns come in several forms, including similarity (things happen the same way), difference (they happen in predictably different ways), frequency (they happen often or seldom), sequence (they happen in a certain order), correspondence (they happen in relation to other activities or events), and causation (one appears to cause another)* (Hatch, 2002, p. 155).

For the in-car interview dataset, the aforementioned coding and analysis process was implemented. It started with reading the data and applying meaningful open-coding to chunks of the data. This was followed by a subsequent cycle of coding that picked through the data sentence-by-sentence, refining the understanding of main themes and sub-themes that emerged from participants' comments.

Lastly, all the themes and sub-themes were grouped and relationships amongst them were identified. Coding verification was achieved through discussions with the PhD supervisors, where additionally consensus was sought on the underlying meaning of problematic or uncertain snippets of data. Although the themes and sub-themes were emergent from the data, they involved terminology that was familiar to the field of product design and evaluations. The themes and sub-themes were therefore defined and clarified with reference to literature. Full details and results from the main study are provided in Chapter 5: Luxury Driving and Interaction Experiences.

3.4 Work Package 4: Design Directions and Suggestions

The fourth work package was designed to provide inspirational insights and examples for Bentley Motors Ltd. The in-car interviews revealed dimensions (principal themes, sub-themes) of designing for luxury in-car interactions and experiences. The principal themes purposefully made use of terminology that is generic and familiar from design and HCI literature. This was to provide easy orientation for Bentley staff regarding the breadth of topics revealed through the interviews. The sub-themes and related details, as well as their inter-relations, were expected to comprise new knowledge for Bentley staff (and indeed luxury automotive manufacturers more generally). In Chapter 5, they were therefore presented as maps of luxury experience in an automotive context, to facilitate understanding amongst primarily designers but other company staff too.

The PhD research up until this point had culminated in visualization and communication of dimensions involved in designing for luxury automotive HMI and interiors. An important next step was to demonstrate ways in which the dimensions and maps could be put to practical use. WP4 involved a period of creative design activity to propose possible routes for new luxury automotive HMI and interiors, justified by the research findings.

To assist in ideation, a systematic review was made of new, emerging and unusual (NEU) interaction technologies that had been applied, or had potential to be applied, to automotive HMI solutions. The technologies were filtered in collaboration with Bentley Motors Ltd. regarding their potential for integration into Bentley in-car environments. A shortlist of fourteen promising technologies was reached, alongside a classification regarding their role in interaction as either (i) input, (ii) input-output, or (iii) output technologies (see 6.1 - New, Emerging and Unusual Interactive Technologies). A portfolio of design ideas – some of which were additionally combined into three coherent design concepts – was created. The concept creation process was based on the Map of LuxUX as a source of dimensions to consider for designing for luxury user experience. The dimensions underlined in the Map of LuxUX is supported by the NEU technologies and formed a matrix of criteria to consider. The matrix can be created with variables other than NEU technologies that designers or companies would like to emphasize for their design process. However, in this PhD the emphasis was on the relationship between new technologies and luxury driving experience. The principal intention of the design suggestions was to illustrate how new theory can be imported into a commercial design process. For this reason, the created design ideas and concepts were primarily for informational and inspirational purposes for Bentley Motors design staff carrying out new HMI-related projects. The main concern was not the evaluation of the design proposals directly, but as a means of exemplifying new theory and design insights whilst designing for a certain type of experience (i.e. luxury). In this regard, the created designs were restricted to an initial set produced only by the researcher; they of course have potential to be appended and expanded through the creative efforts of a larger design team.

3.5 Work Package 5: Provisions for Simulating Luxury HMI

This final work package of the PhD provides a bridge between the interactive product technologies involved in WP4 and developments in digital simulation technologies, specifically virtual prototyping. The evaluation process of in-car experiences (of yet-to-be manufactured cars) has been dependent on the simulation technologies for the last decade. Simulation offers a safe environment for testing out driving experiences, as well as opportunities for evaluating intended user-car interactions without physical mock-ups. The creation of visual and auditory experiences through simulation has advanced significantly, whereas major challenges remain in creating exact tactile, haptic or olfactory information within a simulation environment set-up for prototyping driver-based interactions and different contexts of driving.

The research until this point had established dimensions of luxury user experience for automotive HMI and interiors, produced directions for designing for luxury automotive interaction and UX, and generated design concepts illustrating how the new knowledge could be put into practice within a commercial design process. The final step in the journey was to determine preferred ways for prototyping and evaluating luxury HMI experiences in a digital simulation environment – directly answering the prototyping questions posed by Bentley (and reflected by the industry generally).

As established in Chapter 2, luxury is created as a combination of sensorial stimuli blending into each other and building “an experience”. Therefore, evaluation of luxury experience can be proposed as best achieved with prototyping methods that utilise all (or most) sensory modalities simultaneously.

The aim of WP5 was to gather experts' opinions on how (and whether) simulation technologies can be used to digitally prototype technologically advanced in-car interactions, as part of a feasibility program of research and development. The work comprised an evaluative workshop session (Stewart, Shamdasani & Rook, 2007) with expert simulation staff from the VEC. The experts were probed for their understanding of the opportunities and limitations of various simulation technologies and equipment to achieve effective digital prototyping of multi-sensory in-car experiences during HMI interaction.

Building on the review of interactive technologies carried out for WP4, an extensive document with definitions of the technologies and example product applications was prepared for the workshop. The document was distributed to the VEC experts one week before the workshop, along with instructions to familiarize themselves with its content. During the workshop, the researcher presented the technologies again so as to jog participants' memories. Besides the technologies and definitions, the pre-workshop document also included technology trends and possible locations for the included technologies in a driving scenario, as a prompt for participants to keep in mind during the workshop.

Participants were requested to independently make a professional assessment of the interactive technologies, broadly concerning how to create a simulation of the technologies in a digital environment. They were given evaluation sheets for each technology group (three sheets per person: input, input-output, and output technologies). The criteria to evaluate the technologies were set as: (i) suitability to different reality levels – namely augmented reality (AR), virtual reality (VR) and mixed reality (MR); (ii) availability of hardware and software – if bespoke/R&D solutions would be needed, if commercially pre-existing solutions were available, and if so, whether the VEC had access; (iii) feasibility in terms of R&D time/effort and cost; and (iv) expected impact of a 'successful' simulation of the technology. The individual evaluation process was followed by a group discussion about the technologies and their simulation potential, where each participant contributed from their own perspective. The workshop was video, and audio recorded in its entirety and then transcribed for analysis. Full details and results of the workshop are presented in Chapter 7 – Provisions for Simulating Luxury HMI

3.6 Summary

The methodology for the PhD research can be summarised in the following five steps.

1. Literature review. An extensive literature review on UX, the concept of luxury and automotive HMI was carried out, to reveal existing theories that could feed into the research as well as gaps and opportunities where research could generate valuable new knowledge.
2. Orientation study. A benchmarking study involving HMI evaluation of four luxury cars was made, serving as an orientation study in luxury product design for the researcher as well as establishing first insights on trends, product designs and UX for luxury automotive HMI.
3. Main UX study. A wide-ranging and large-scale main field study was carried out through in-car interviewing with drivers, focused on evaluation of the design and UX of automotive HMI of drivers' cars, as well as drivers' projections for luxury experiences from in-car interactions. New knowledge and understanding of the dimensions of luxury HMI experiences were established through the data analysis.
4. New automotive HMI concept designs. As a means to show the practical implementation of the research findings and to create a source of information and inspiration for Bentley Motors Ltd, new automotive HMI ideas and concepts were generated. The ideation focused on synthesising (i) the results of a technology review into new, emerging and unusual interaction technologies, with (ii) the results of the main UX study.
5. Provisions for virtual prototyping. A workshop with digital simulation experts from the VEC was conducted to assess the simulation potential of the new automotive HMI ideas and concepts, providing practical advice to Bentley Motors (and other luxury automotive manufacturers) on how to extend virtual prototyping methods to include effective simulation of interaction aspects of HMI design.

CHAPTER 4

FOUNDATIONS OF LUXURIOUS AUTOMOTIVE HMI

This chapter focuses on the study carried out to reveal the descriptors of luxurious experience in the automotive context. The study was an orientation study for the researcher to understand the concept of luxury and familiarise herself with the details communicating luxury in car interiors. The method used was immersion (Jordan, 2000) - that is, immersing the researcher into luxury car interiors to observe, experience, take notes and analyse the design features communicating luxury. This study revealed trends and future directions for car interiors, especially regarding the HMI system as well as details communicating luxuriousness to drivers.

4.1 Orientation Study – Benchmarking and Trend Analysis

The factors introduced in the literature review chapter about building luxury value in the automotive industry have been mostly at an overview, broad-perspective level, incorporating macro interactions of a brand's products with its consumers. What the literature is not so clear on is how in-car interactions – and the specific details of product design – impact on luxury value. That is, how the practicalities of a car interior and its HMI are influential in supporting or detracting a luxury experience. Questions remain, e.g. how are luxury car interiors experienced? what are the qualities of interaction scenarios in luxury cars? how is the sense of luxury communicated through the materialized features of luxury car interiors? Answers to these questions were not found in the literature. Therefore, for the preliminary investigation, an orientation study was carried out in collaboration with Bentley Motors Ltd. This section reports the details and results of the study.

On the path to improving in-car HMI, it is crucial to first have a good understanding of existing car solutions and to identify problems and opportunities. The orientation study was designed for exploring and understanding in-car interactions, in order to: (i) analyse typical HMI layouts, (ii) identify control locations and trends, and (iii) for the researcher to become sensitized to the design of luxury car interiors through personal hands-on experiences.

4.1.1 Selection of cars

For the study, Bentley Motors Ltd. provided their facilities and particular car brands and models for the researcher. The criteria for selection of the car brands and models were based on Bentley's assessment of the market position, competitor brands and availability. Four different luxury car models from four different brands were used for the study (Mercedes AMG GLE, BMW X6 M, Audi TT, Bentley GT).

4.1.2 Data Collection

The necessary arrangements for the data collection process were organized in collaboration with Bentley Motors Ltd., who supplied the venue and equipment. The process was carried out in four separate sessions on 07 December 2015, 08 December 2015, 23 February 2016 and 29 February 2016, based on the availability of the venue and cars. Each session lasted approximately one working day (5 to 6 hours), making a thorough testing and evaluation of each car's HMI system and an appraisal of the interior design. The necessary equipment for collecting images and videos on-site was provided by Bentley Motors Ltd. (camera, SD cards, computers etc.).

4.1.3 Data Analysis

The analysis process was carried out by the researcher with the benefit of concepts and findings from the literature reviews reported earlier in the thesis. The process started by marking-up the location of controls and information on the whole dashboard area onto photographs of the car interiors. This facilitated a comparison of the cars regarding HMI layouts and configurations. Colour coded visuals were used to identify the similarities and differences between the car models.

Following that process, concentration was directed onto the driver area, again focusing on the location of controls and information. The general focus was on the steering wheel, since this control is becoming increasingly interactive in the last five years, as well as additional screens for understanding screen-based information. Possible repetition of controls and information on the central stack and driver area was the main point for the analysis, providing insights about the migration (and possible lack of integration) of controls and information to the driver area.

The analysis also included an examination of the relationship between the interactive menu structures and controls of the cars. The main criteria were comparing the movement of the controls and their mapping to the menu structure, the layers of information, and the number of steps that are required to access certain functions and screens. Lastly, the realization of luxury controls was questioned, in terms of materials and execution, changeability of interior elements and customisation possibilities.

4.1.4 Results

The results are grouped under four themes based on the research interests; (i) driver area and driving related controls, (ii) customisation options, (iii) relationships between GUI menu structure and controls and (iv)luxury interaction cues in cars.

From the analysis of the cars, the first findings are related to the location of the controls and information in all cars. These locations are colour-coded in Figure 15 to highlight the similarities and variations in each model. The general differences about the locations of the controls can be linked with brand identities and design, or they can be linked with the different type of controller choices (e.g. touchpads, knobs and buttons). Figure 15 also shows similarities in the mapping of controls, especially regarding the air conditioning and seat heating which are located in the central stack within easy reach of both the driver and passenger.

Figure 15. Colour-coded car interiors

The main differences and similarities are presented and discussed in the following sections, considering the driver and driving-related controls, customisation options, relationships between GUI (graphical user interface) menu structures and controls, and luxury interaction cues.

4.1.4.1 Driver Area and Driving-Related Controls

The distribution of information and controls in cars is based mainly on driving-related activities and the safety of the driver and vehicle. Geiser (1985) classically classified driving into primary (how to manoeuvre a car) secondary (functions that increase safety) and tertiary (functions related with entertainment and information systems) tasks, based on their relationship (proximity) to the principle goal of operating the vehicle. These three task classifications inevitably have a hierarchy. For example, primary tasks require instant access since they are highly tied to safety and can cause fatal errors, whereas tertiary tasks are not urgent and result in lesser consequences such as annoyance or frustration. This hierarchy is reflected on the in-car environment, most notably the location of HMI (human-machine interface) elements related to the tasks.

The HMI elements related to primary and secondary tasks are located closest to the driver (e.g. around the steering wheel) whereas HMI for tertiary tasks is generally located on the central stack. Whilst these general observations are still relevant, the introduction of new interactive technologies is starting to raise questions about the ideal location of HMI elements and their relation to driving tasks. Driver assistance systems allow drivers to divert some of their attention away from primary and secondary tasks and onto tertiary tasks (e.g. music, communication) that enrich the driving experience. Within the car interior and dashboard, these technological-driven changes can be seen to bring infotainment-related HMI elements closer to the driver (Figure 16). Most of the driving and infotainment-related controls are being transferred onto the steering wheel and/or stalks, which is one of the areas that drivers are constantly physically interacting with. Therefore, steering wheels are being populated with small-sized, intricate physical controls that try to give access to the vast quantity of data that is presently provided through each of the four cars' main screens. Importantly though, many of the controls on the steering wheel duplicate controls found elsewhere in the car (e.g. on the central console), which introduces problems of visual clutter and operational redundancy.

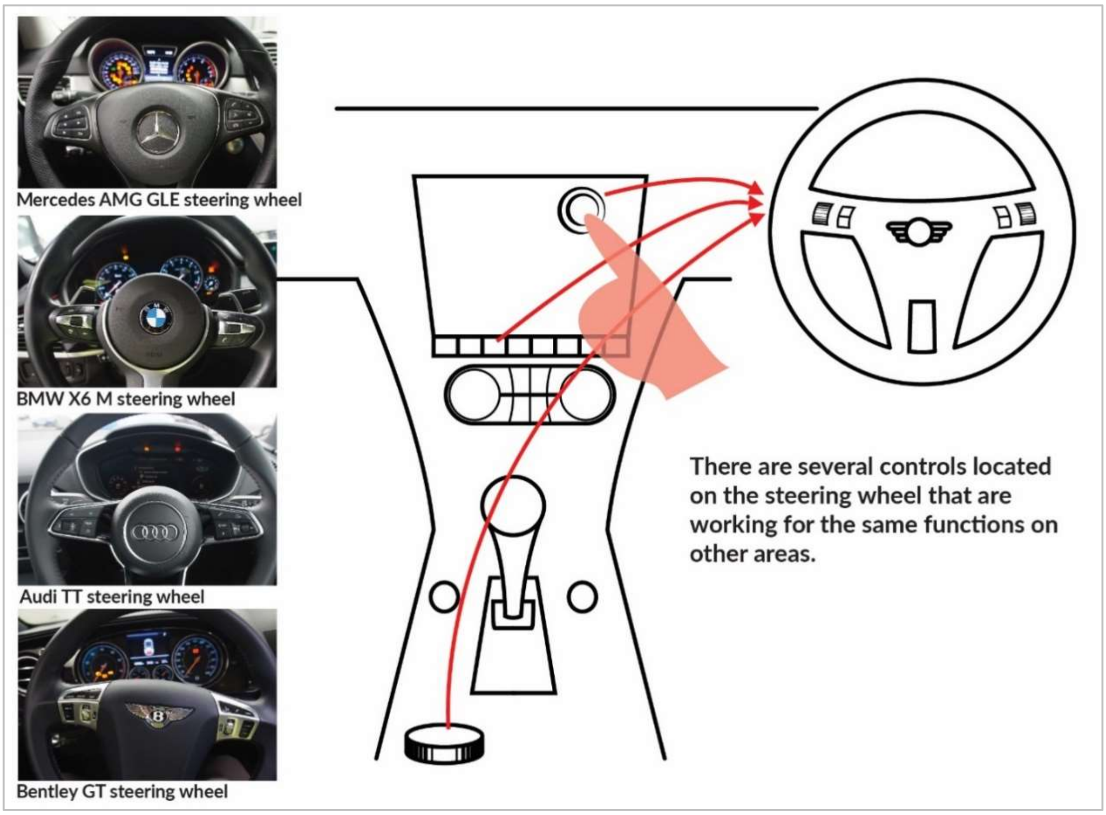

Figure 16. Examination of controls moving closer to the driver and onto the steering wheel

The driver area is one of the most evolving areas in automotive design. Since by definition the driver is in control, most of the information and driving-related controls are required to be located within the driver's immediate (non-extended) reach. However, the information that is presented to the driver – whether statutory or optional – is becoming voluminous and potentially denser as each car generation is created. To deal with this, technological advances have made it possible to present a certain amount of information in a limited area or convey information with senses other than visual. As well as HMI inputs, the communication of information is also moving closer to the driver.

Figure 17. Information moving close to the driver, with behind-wheel displays becoming more content-driven

Although the benchmarked cars still have central screens (as seen in Figure 17), these are supplemented by smaller screens directly in front of the driver behind the steering wheel. In older cars, this area was used only for driving-related information using an analogue speedometer (vehicle speed), tachometer (engine revolutions per minute) and odometer (distance travelled). In the benchmarked cars, the screens in this area digitally display such driving-information, but also include infotainment information (e.g. radio station, song name, navigation instructions) and able to transfer and display the content of central screen. A few commercial cars, not included in the benchmarking study, have extremes, dispensing their central screen for one that is carried to the main instruments area behind the steering wheel.

However, it should be noted that with the on-going development of alternative screen developments (e.g. head up displays), the interaction experiences of dense an LCD display, as well as the duplication of HMI functionalities through multiple controls, is in a state of transition. Companies are trying to find better arrangements and applications of new technologies.

4.1.4.2 Customisation Options

The ability to customise is nowadays a standard feature on many everyday digital products, yet within cars there is presently little implementation. Where present, it is usually found between layers of interactive menus, and regarded as a 'set once and forget' feature. Greater customisation may be a point of differentiation for driver experience in next generation cars, as well as provision for multi-user cars.

The Audi TT provides its drivers flexibility through screen technologies. During navigation, this flexibility is accessed on-screen through the 'view' button (Figure 18 - top row). This button reduces the dimensions of the speedometer and tachometer, to enlarge and prioritize the map and directions. Flexibility can also be achieved through personalized controls, such as the function of the 'star-labelled button' on the steering wheel that can be defined by the driver (Figure 18 – second row). This button may be used for options ranging from activating voice guidance to switching between radio/media. This gives the driver flexibility and freedom to define what she/he wants from closely located controls.

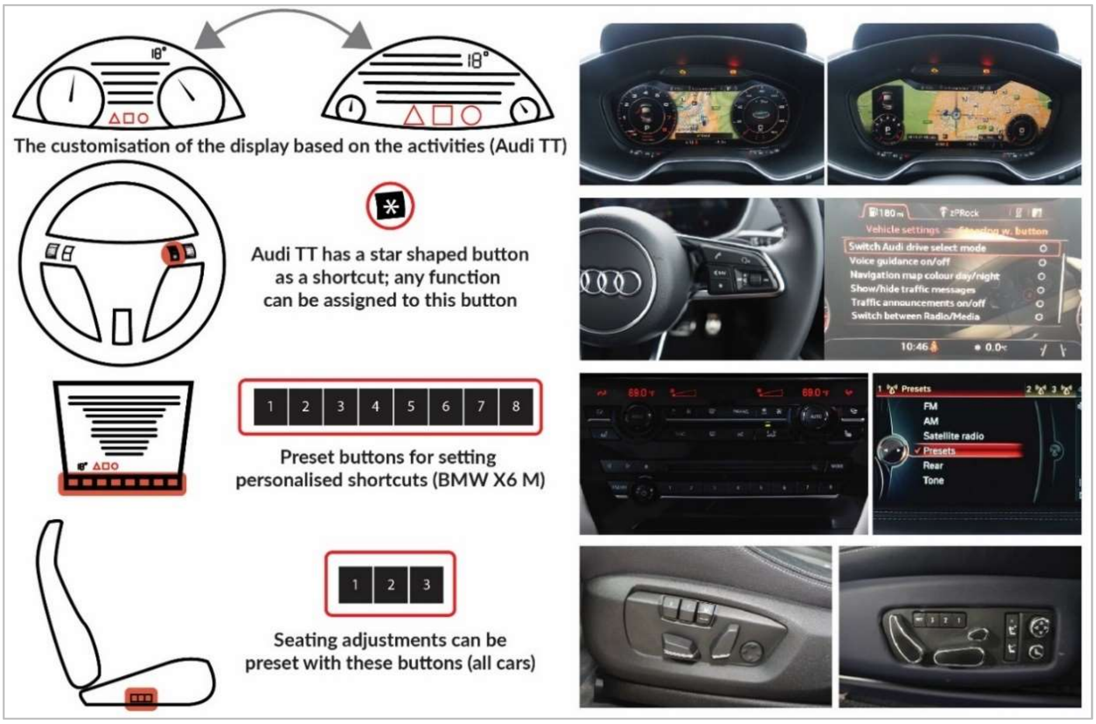

Figure 18. Customisation options offered in benchmarked cars

The BMW X6 M also offers a similar application through bookmark buttons (Figure 18, third row) located under the central screen. This has eight buttons that can be user-defined for different functions. These buttons can be assigned the functions of navigation to a particular address, specific pre-set radio stations or media and even audio contacts.

Finally, the seating arrangements can be controlled through the buttons located near the seats (Figure 18, bottom). These buttons provide drivers the ability to adjust their seating and then save a snapshot of the position. These pre-set positions allow quick and easy recall for different driving modes or multi-driver scenarios.

Considering the spread of mass customization in today's products, it appears that cars are an ideal product with long-term usage that has great potential to be customised. The technologies facilitate different ways of customisation. For example, new display technologies (i.e. see-through displays, head up displays) could support flowing interiors with different materials through concealing the screen when it is not in use. There are many attempts and examples in cars for customisation but still car interiors are not designed with the flexibility of technologies. As cars become more equipped with these flexible technologies, customisation will likely be more available for users.

4.1.4.3 Relationships between GUI Menu Structure and Controls

Car interiors are currently visually and operationally dominated by large touch screens located on the upper region of the central console. These screens have the advantage of a large surface area for clarity of information presentation but are repeatedly reported as difficult to use in car tests, especially whilst driving (Ferris, Suh, & Miles, 2016). We have become used to such technology in our tablet computing devices and smart phones, but when combined with the complexity of attention for driving, the required level of interaction for a touch screen becomes troublesome. Some manufacturers have tried to circumvent these problems by providing multifunctional controls as a surrogate for direct touch screen interaction.

One of the challenges that car designers face is to provide access to a wide range of car functionality but within a physically very limited area for interaction, since controls and information provision should be located within reach of the driver. This challenge is most acutely noticed for the steering wheel. Designers will often develop solutions that rely on ingenious controls that combine different actions (e.g. thumbwheels that are rotated to browse through a menu structure and pushed like a button to confirm a selection). This is a common approach for navigating a touch screen without touching, which brings obvious benefits when driving. However, such controllers can have drawbacks: firstly, manufacturers (perhaps unwisely from a usability perspective) sometimes link the multiplicity of actions to duplicate functions (e.g. toggling a knob left, or turning a knob counter-clockwise and pressing the back button results in upward navigation in a menu structure); secondly, the actions should ideally be mapped to the menu navigation thoughtfully to avoid confusion (e.g. in a menu designed as header and footer lines located horizontally, as shown in Figure 19 – left: the continuous action of turning the knob may result in confusion since the expected outcome is for the menu marker to move continuously, however it is limited with the menu items and the menu marker does not move in a loop). Multifunctional and multi-action controls require learning and memorising and are not standardized across cars.

Figure 19. Multi-action, multi-function controls

During the benchmarking, complexity and access to information was experienced to be the main problems with menu-driven in-car displays. This is because the space available is still relatively small for the viewing distance, compounded by a requirement for breadth of information (large number of categories) as well as depth of information (sub-category trees). Hierarchical (tree-like) organisation is a well-used method for information presentation in such displays, but problematic when the driver is concentrating on the road and not able to give the necessary attention to navigate around screen content. Maintaining a sense of location and history within a hierarchical menu structure is crucial (Figure 20) but difficult to achieve and concentrate on during driving – especially if using rarely-accessed functions.

Figure 20. Layered information structure of BMW X6 M

The physical dimension of interaction is important with screen-based interaction. From a basic driving perspective, it is relatively easy to switch from one car brand and model to another because of common physical HMI locations and reliance on muscle memory. With screen-based interaction and new technologies/controllers, each brand risks creating their own idiosyncratic interaction language that requires time and practice to master.

4.1.4.4 Luxury Interaction Cues in Cars

Luxury interaction has no concrete definition, as it is highly related with subjective qualities but on the other hand, it is possible to catch luxury cues from properties of luxury products. Luxury products very often communicate luxuriousness through certain materials and finishes. The benchmarking study confirmed that materials and finishes were a dominant aspect of the HMI and interiors of the four luxury cars. The cars are generally equipped with traditionally hand-made leather accessories and seats, which represent the expertise and experience of the brand. Another material that is observed in luxury cars is wood, with its unique patterns that enhance the exclusivity of the car. Metal is another material that is used in luxury cars, often in the places where ordinarily dark and dirty-feeling plastic parts are used. Metal controls feel physically cold and heavy, leaving a fresher and cleaner feeling. Also, finishing details are crucial to communicating superior quality, such as the Audio TT with its metal parts with patterned finishing, and controls with intricate details that make it easier to grab, feel and use (Figure 21).

Figure 21. Use of metal in Audi TT controls

The feeling of expertise and professionalism can stem from the exceptionally well finished and fitted parts and controls, which feel firm and confident to the touch. The controls (i.e. knobs, buttons) in the benchmarked cars are finished in a precise manner to keep them functioning and give the feeling of trust that congruous with the vehicle's performance. The precision of mechanisms and use of durable materials also create consequential sounds that are typically evaluated positively, again supporting the feeling of competence, trust and performance.

Furthermore, the four benchmarked cars are designed in a way that gives the driver a sense of being serviced. This sense can be observed from dynamic interior elements, such as the safety belt that gets closer to the user after closing the door in the Bentley, or the steering wheel in BMWs that gets closer to the driver when the engine start button is pushed. These dynamic interior elements do not require manual intervention by the driver; they effortlessly place the right set-up into the driver's hands.

The major specific criticism of the interiors of the benchmarked cars relates to the infotainment systems. Even though some of them are designed with good mapping and hierarchy, these systems still lack in catching up the quality and consistency of the rest of the car interior. To design the interactive elements and their content with a luxury approach still remains a major challenge for car designers.

CHAPTER 5

LUXURY DRIVING AND INTERACTION EXPERIENCES

The foundation of the luxury car industry has been the performance, high quality, precise/detailed craftsmanship and use of unique and expensive materials. However, interactive technologies have become a new variable for luxury in the past few decades. The technology-driven changes in all product sectors has caused us to become addicted to information and also forced many products to become compatible with this change. Luxury driving scenarios have been mainly dependent on performance related technologies and developments but today technology is not only supporting the performance, but it is also a part of the designed experience. Interactions can be realized with new technologies in a way to communicate more than just performance and precision, extending into the communication of meaningful experiences such as a sense of luxury, sportiness or an elegant feel. The concept of luxury is not limited to supreme production quality, fits and finishing details but also is now expected to be delivered through the various ways we communicate with products.

The second study conducted for the doctoral research was planned as wide-ranging and comprehensive in scope. It aims to reveal what kinds of product features are relevant to pursue (or avoid) when designing for luxurious driving experiences. In order to find the answers to the following research questions, 28 semi-structured interviews were carried out with Bentley staff in which questions were asked to understand what provides the luxury perception to them on the basis of their own driving experiences.

SRQ.1. *What are the descriptors of luxurious interaction in automotive HMI?*

- How people define luxurious HMI in their own cars?

- What kind of design features communicate luxuriousness to the driver in a car?

- How can we reflect the NEU (new, emerging, unusual) interactive technologies to car interiors addressing luxurious interaction?

5.1 Interview Plan

The interviews were planned as a generative process supported with visual probes and open-ended questions to reveal constructs for luxury driving scenarios. Each interview lasted on average approximately 30 minutes and consisted of three stages, carried out in participants' own cars that they drove to work on the day of interview, thereby keeping their in-car interaction experiences fresh in the memory.

Before the interviews, participants were introduced to the aim and process of the interviews and they were asked to read the participant information form (Appendix C) then fill in the consent form (Appendix D). Ethics clearance from the University of Liverpool had been secured prior to the commencement of the interviews. The briefing process was followed by a short walk to their car (within the Bentley staff car park area) and the interviews started after entering into the car. During the interviews, participants were asked to sit on the driver's seat whilst the researcher sat on the front passenger seat, carrying out the interviews and managing the audio/visual recording process. The details of the process are summarised in Figure 22.

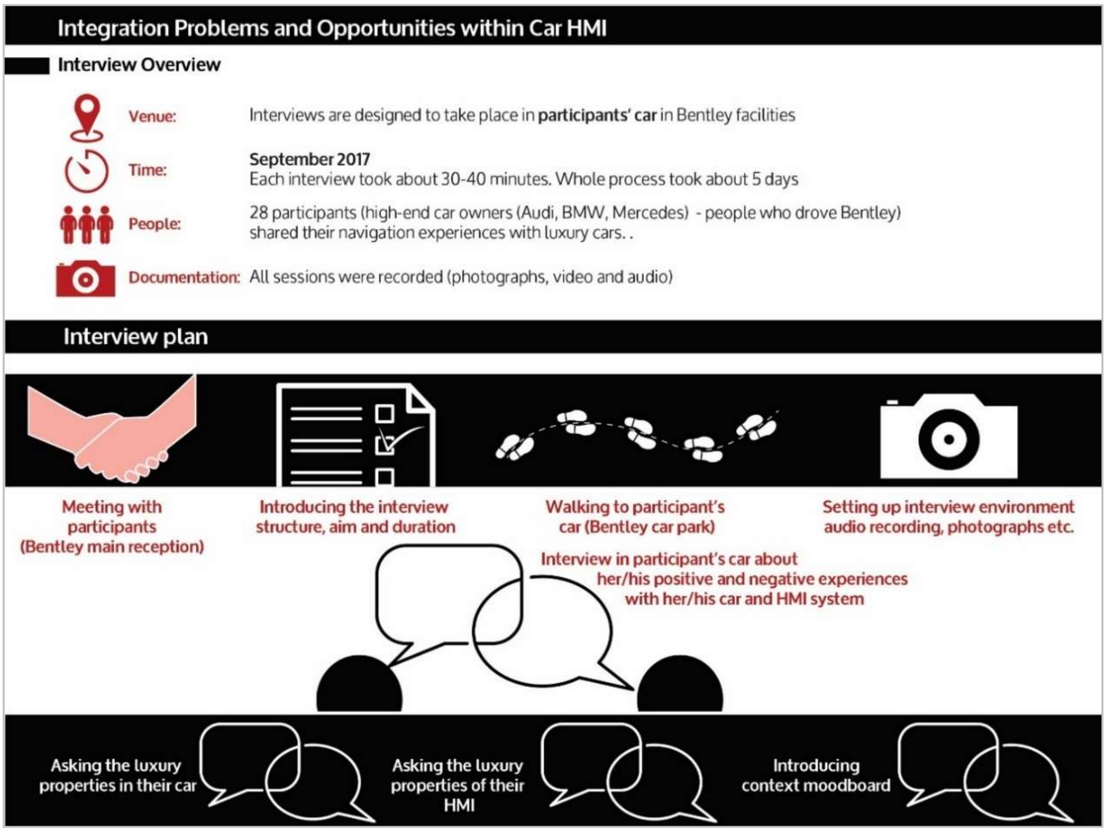

Figure 22. Interview plan

There were three consecutive stages of the interview, starting with general questions about their car and the concept of luxury and gradually narrowing the focus to the car HMI system. The first stage was about the general concerns about luxury cars and HMI, the second stage was the luxury experiences in specific contexts and the third stage was about what else could conceivably be done to communicate luxury. These stages are summarised below.

Stage 1: This stage is designed as an ice-breaking activity, stimulating participants' thoughts and memories about driving and their concepts of luxury driving. Questions asked were:

- *Do you find anything luxury in your car? Please explain what makes that area luxury? Why?*
- *Do you find anything luxury about your car HMI system? Please explain what makes that area luxury? Why?*

Stage 2: This stage is designed to stimulate the memories of participants by presenting context information to represent pleasing or annoying experiences with their HMI system. For this reason, a mood board (Figure 23) was prepared beforehand to share with the participants whilst carrying out this stage of the interview. The mood board was designed with images resembling four factors (environmental factors, social factors, personal factors and technical factors - adapted from Roto, et al. 2011), which are known to condition user experience such that the lasting experience in one context might be quite different to that of a different context. The images were found through a 'Google image search' with the keywords agreed through discussions with Bentley Motors. The keywords were also included as text on the mood board, to encourage the participants to spend more time and be more attentive while looking at it.

After introducing the mood board, the participants were informed how context affects user experiences and were then asked to explain their positive and negative experiences with their current car HMI system. The questions asked were:

- *Is there any specific context that you have a really nice experience with your car and HMI? (they are offered to choose from the board or talk about any other context) Could you talk about the details?*
- *Is there any specific context that you have a really annoying experience with your car and HMI? (they are offered to choose from the board or talk about any other context) Could you talk about the details?*

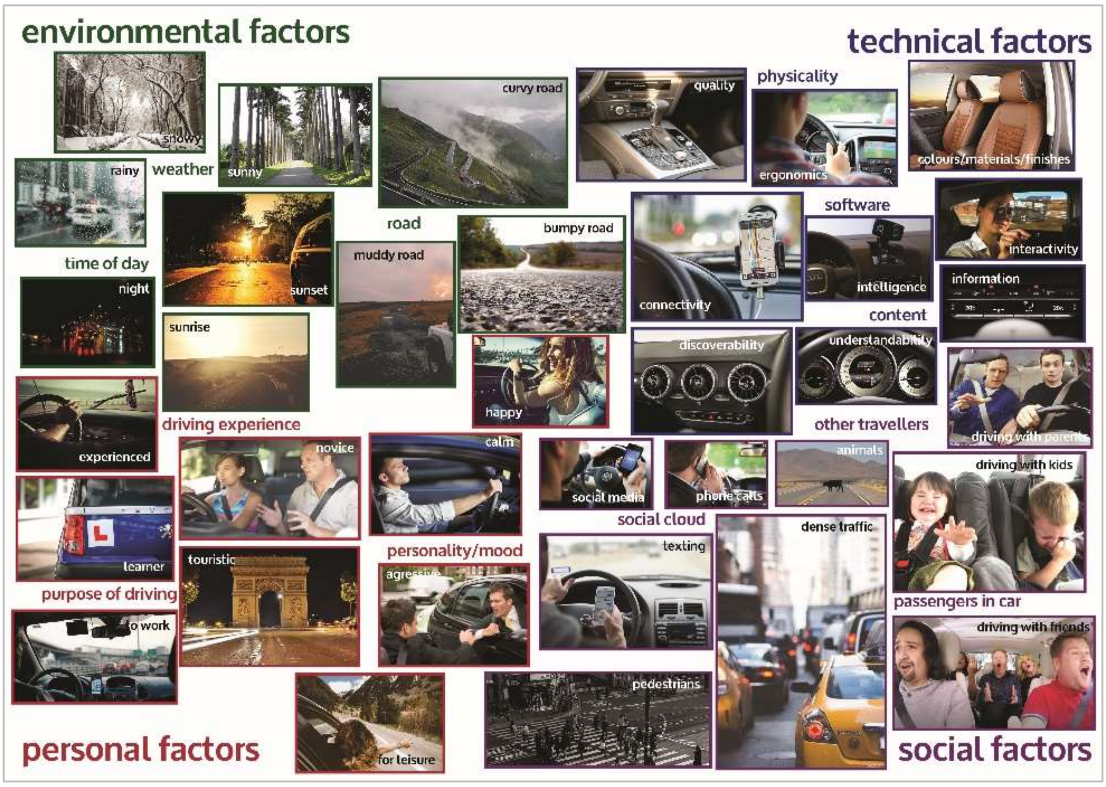

Figure 23. Contextual factors affecting the experience

Stage 3: The last stage comprised closure for the interview process, with a single objective to ask participants to talk about what could have been done to enhance the luxuriousness of their in-car experiences. The question was:

> *- Thinking about all the experiences that we have talked about, what else can be done as "a cherry on the top" for your experience enhancing the luxuriousness of your car?*

5.2 Selection of Participants

It is not an easy task to find a sufficiently large number of luxury car drivers to carry out interviews with, so the recruitment process was carried out in collaboration with Bentley Motors. For reasons of confidentiality, it was not possible for Bentley to share their customer database as a ready source of potential participants. Therefore, as an alternative approach, the participants for the interviews were recruited from amongst those company staff members who occasionally drive Bentleys as part of their job (especially including Bentley staff from departments such as interior architecture, design, marketing). Additionally, these participants work on the process of design and development of Bentleys on a day-to-day basis, and are owners and drivers of mostly premium, high-end cars in their daily routine.

The final participant sample criteria were agreed with Bentley and participant selection was mainly based on voluntary involvement and availability.

The recruitment process was carried out through a contact person at the firm, who advertised the interviews with an e-mail explaining the aim of the study to the target group. Then an online calendar was set up and shared with all parties consisting of one-hour time slots for each participant. Interview appointments made through the online calendar and a schedule has been set in a few weeks' time. The number of participants were 28 (11 female, 17 male) with ages ranging from 25 – 63 and with a mean value of *M*=43.8 Table 1. The intention was for the gender ratio to be kept equal, but the skewing towards male participants reflected the gender distribution of staff within the relevant departments of the company. However, gender effects were not anticipated to be strong for the posed interview questions and there was no intention for gender effects to be included as part of the analysis. The ratio of male and female participants was therefore considered suitable for the study.

AGE RANGE	FEMALE	MALE
25-35	1	1
35-45	6	8
45-55	4	7
55-65	0	1
SUM	11	17

Table 1. Participant information

5.3 Data Collection Process

The interview schedule was set beforehand and all the participants were asked to drive to and park at the Bentley car park on the day of the interview. Since all the participants were Bentley staff, the facilities of Bentley were the most efficient area to carry out interviews in respect of time, travel expenses and scheduling. For this reason, it was agreed with the contact person to set the Bentley reception as a base for meeting with the participants before the interviews. At the Bentley reception, the participants were introduced to the study details and necessary documentation; i) participant information form (Appendix C) and ii) consent form (Appendix D). During this time, the necessary participant information comprising age, driving experience, brand model and production year of their car was collected and noted (Table 2).

Participant	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	MEAN
Age	41	36	48	42	46	44	50	44	37	41	25	36	53	45	51	49	47	50	33	45	39	44	52	43	40	43	40	63	**43,8**
Driving Experience (years)	23	19	31	24	29	26	33	22	19	24	8	19	35	27	34	32	20	33	14	29	21	27	29	24	22	25	23	46	**25,6**
Cars' age	2	0	13	0	0	0	0	0	0	0	0	0	4	0	6	0	9	2	0	0	0	2	0	0	1	1	0	0	**1,4**
Car Model/Year	Vauxhall Corsa 2015	Audi Q5 2017	Jaguar X Type 2004	Bentley Bentayga 2018	Audi A5 2017	VW Scirocco 2017	Seat Ibiza 2017	VW Tiguan 2017	Audi S3 2017	Audi A4 2017	VW Golf 2017	Audi A5 2017	Mazda MX 5 2013	Audi S5 2017	VW Passat 2011	Audi A6 2017	Land Rover Discovery 2008	Volvo XC70 2015	VW Touareg 2017	VW Golf 2017	Audi A4 2017	Range Rover Evoque 2015	Audi A5 2017	Seat Leon 2017	Audi Q3 2016	Audi Q5 2016	Audi Q5 2017	Mercedes 350S E Class 2017	

Table 2. Participant age, driving experience and car model/year

The briefing process was followed by a short walk to participants' cars parked at the Bentley car park. Interviews were carried out within their cars in a parked position for safety reasons, but their HMI system was activated and 'live' during the interviews. Methodologically, the car interiors were expected to become visual stimuli for the participants to talk about their experiences and memories with their car HMI system. Moreover, the participants had the ability to point out the exact controls and/or information that they were talking about during interviews. This was considered a crucial advantage over retrospective interviews or interviews that would take place outside of a real car environment. Additionally, this research set-up was useful during documentation and transcription of the interviews, helping to make sense of the data in terms of precision and detail.

During the interviews the researcher managed the filming of the process with a handy cam, which offered the required flexibility to focus on interface details and specific areas of the car interior that participants talked about. During the session the camera was moving, in order to keep participants out of the scene and instead focus on the specific areas of interest. In addition to the camera, an audio recording application (mobile phone) was used to keep recording audio details in case of any problem occurring with the audio recorded with the handy cam. All the recorded audio-visual information was uploaded to the researcher's personal computer after each session. After organising the files (naming, organising and compressing), the dataset was transferred as required by the research Code of Conduct to the *M Drive* space provided by the University of Liverpool specifically to securely store research project data.

5.4 Data Analysis Round 1

The initial step for the data analysis process was to transcribe all the data using Microsoft Word software. The transcription process was not only done by listening to the audio recordings but also watching the videos to specify the areas that the participants were interacting with. By doing so, most of the transcribed sentences also include the actions of the participant and/or the area that they were talking about. This can be exemplified by the comments of participants 13 and 14, with the comments in italic-bold indicating actions.

> *"I think if it was located close around steering wheel I don't know if it could be possible to be here I think that would be something that you have to look at (**the central screen**) because you get used to coming to central console to do things but if you get something here (**around steering wheel**) that you looking into here (**steering wheel**) and the central screen." (P13-23)*

> *"Perhaps just refined touch would be better, so you would actually (**he gently touches the buttons**) but it doesn't you got to press the button." (P14-21)*

5.4.1 Classification and Organisation of Dataset

After the transcription process, the full dataset was transferred to Microsoft Excel for classification of the comments. There were approximately 700 individual data rows that were classified, organised and coded during the analysis process. The classification includes:

- PARTICIPANT / USER NUMBER and COMMENT NUMBER; *for keeping the track of the comments. In the following sections the comments will be referred with these numbers i.e. P11-05 for the 5th comment of the participant 11.*
- TRANSCRIPT SOURCE - INTERVIEW STAGE; *STAGE 1 - Luxury Detail, STAGE 2 – Contextual HMI System, STAGE 3 - Luxury Reflection*
- WHERE? REFERENCE LOCATION - DRIVER HMI; *Whole Dashboard / HMI, Instrument Panel, Steering Wheel Controls, Central Screen, Central Controls, (Non-Specific / Generalized)*
- WHAT? PHYSICAL/MATERIAL UX - SENSORY MODALITY; *Visual Experience, Touch Experience, Haptic Experience, Audible Experience, Smell Experience, (Non-Specific / Generalized)*

- WHICH? LUXURY UX - VALUE TYPES; *Financial, Functional, Symbolic, Experiential* (Yardim Sener, Sen, Pedgley, Sener, & Murray, 2016)

Table 3 provides an example fragment of comments and classification that is typical of the full dataset transferred to the Excel spreadsheet.

		WHERE? REFERENCE LOCATION						WHAT? PHYSICAL/MATERIAL UX						WHICH? LUXURY UX			
		DRIVER HMI						SENSORY MODALITY						VALUE TYPES			
Participant / User Number	**Raw Data Transcript**	Whole Dashboard / HMI	Instrument Panel	Steering Wheel Controls	Central Screen	Central Controls	(Non-Specific / Generalized)	**Visual** Experience	**Touch** Experience	**Haptic** Experience	**Audible** Experience	**Smell** Experience	(Non-Specific / Generalized)	Financial	Functional	Symbolic	Experiential
U4-07	It is nice to have heating and the cooling in the seating as well so you sometimes leather during summer time it can get very hot so can keep the ventilation going on.						x		x								x
U5-07	Starting within the car you know this sort of brushed finish that appears everywhere throughout the car and throughout the most of Audis.						x						x				x
U7-21	That's why I would prefer more buttons here (steering wheel) because you're interacting with the screen (instrument clusters). I'm less inclined to use the central screen.		x	x									x				x

Table 3. Example of classified dataset

As it is represented in Table 3**Hata! Başvuru kaynağı bulunamadı.**, each verbatim sentence from each participant's transcript was written one by one into an Excel row. Sometimes sentences included more than one area or main concept. For this reason, the coded/classified fragment of the comments relevant to each Excel row were coloured red. The initial findings from the classification and organisation process are explained in the following section.

5.4.2 Results Round 1

After all the data were classified according to the titles listed, the findings were mainly quantitative results to understand the distribution of the data within those titles. This quantitative data was quite useful for the filtering and refinement of the dataset into more understandable pieces.

Classifying the data according to the stages of the interview was useful for grouping some of the data during the coding process, as the first stage mainly concentrated on the 'luxurious' interior and HMI details existing in participants' cars; the second stage was for stimulating their memories and previous experiences for getting more detail regarding their HMI system in different contexts; and the last stage was a reflection of the whole discussion and elicitation of further comments and recommendations from participants about their car interiors with regard to communication of luxury. The distribution of participant comments explained in detail within the following sections based on the reference location, physical / material UX and luxury UX.

5.4.2.1 Classification of User Comments Regarding the Reference Location

The reference location group consisted of the dashboard elements such as steering wheel, instruments panel, central screen, central controls. Some of the comments were not about a specific location but about the organisation of the whole area, grouped under the whole dashboard section. However, there are comments not related with the dashboard elements but rather the general experience and information, which have been grouped under non-specific / generalised. This can be exemplified by the comments of participants 11 and 16.

> - *"I think it's ease of use and convenience I think to make your life easy and more comfortable makes it feel luxury." (P11-05)*
>
> - *"Easy information, easy to find, suggesting where I want to go without too many unusual button clicks" (P16-31)*

There are other comments referring to more than one area which are classified under two or more groups such as the comment of participant 7.

> - *"That's why I would prefer more buttons here (**steering wheel**) because you're interacting with the screen (**instrument clusters**). I'm less inclined to use **the central screen**" (P7-20)*

Classification of data according to the reference location were useful during the process of coding and clustering to reveal similarities/differences between the comments and repeating patterns about the most/least areas of interaction. The distribution of the comments according to the reference location is represented with a graphic on Figure 24. As it can be seen on the graphic, more than half of the participant comments were not about a particular area of interaction. Those comments were mainly on the luxury experiences that people would like to achieve in a more general sense, through careful design. Some examples are mentioned at the start of the section (*P11-05, P16-31*), other examples are listed below the comments of participants 8, 10 and 12.

- *“So you're not you're not [sic] in a harsh environment it's a comfortable environment” (P8-11)*

- *“I would say partly luxury is thinking that I got something different so I wouldn't get in perhaps at a lower value car” (P10-04)*

- *“Well the metal, the leather is obviously traditionally [sic] for the luxury segment so when you look at furniture traditionally leather and natural wood associated luxury market” (P12-07)*

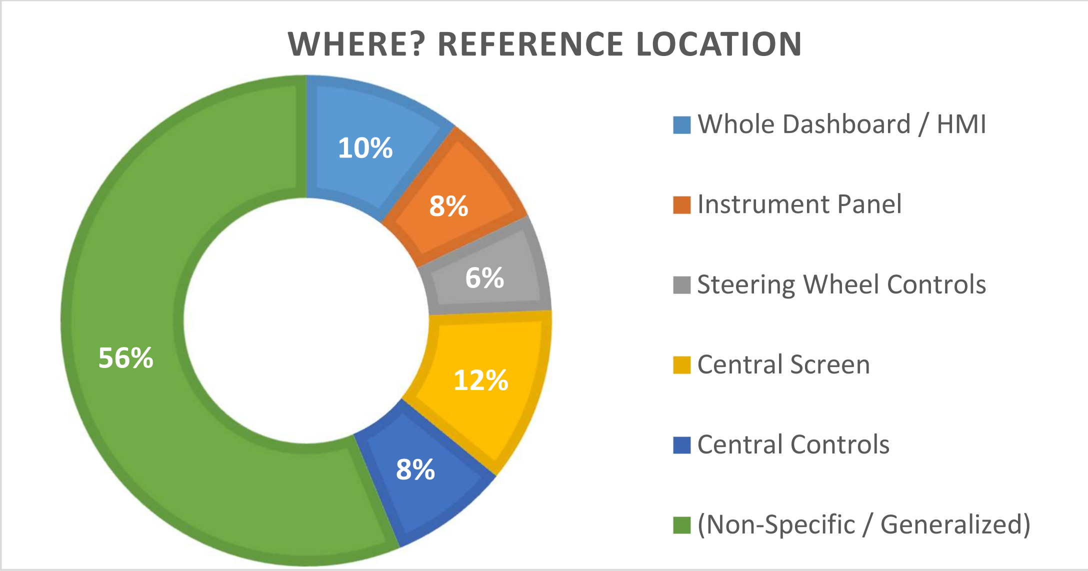

Figure 24. Classification of user comments regarding reference location

The percentage of areas that people talk about or reference during their discussions are quite close to each other, however the central screen as the main information presentation area in cars received more attention than others, as expected. The instruments panel area and steering wheel controls received less attention than others as they are relatively new areas of interaction in comparison to the central screen and controls. There are also comments about the general organisation of the whole dashboard, which are coded under the ‘whole dashboard HMI’ area, such as the comments of participants 13 and 16.

- *“It would be nice* ***if some of these finish (dashboard) is a little bit different****, but you're restricted you don't get the choices that you can with a Bentley” (P13-16)*

- *“I guess the ergonomic positioning of the controls, interface it needs to be close I don't want to stretch” (P16-32)*

5.4.2.2 Classification of the User Comments Regarding the Physical UX/Material UX

The second step of classification was the physical/material UX regarding sensory modalities. This classification includes sensory modalities; (i) visual, (ii) touch, (iii) haptic, (iv) audible, (v) smell and (vi) non-specific/generalised titles. The percentage of comments is represented with a graphic on Figure 25. The comments of participants were mainly classified under the non-specific/generalised title, as most participants defined 'an experience' but did not specifically focus on the details of which modality would be involved. These comments were mainly explaining how they would like to be supported by their car in certain circumstances regarding the information, or general organisation as in the previous example of *P16-32,* which is followed by the P16-33;

> - *"I don't want it to get in the way of my driving* ***experience I want it to be a part of my driving experience****" (P16-33)*
>
> - *"The number of* ***extra features,*** *I don't use most of them most of the time but they're nice to have" (P17-05)*

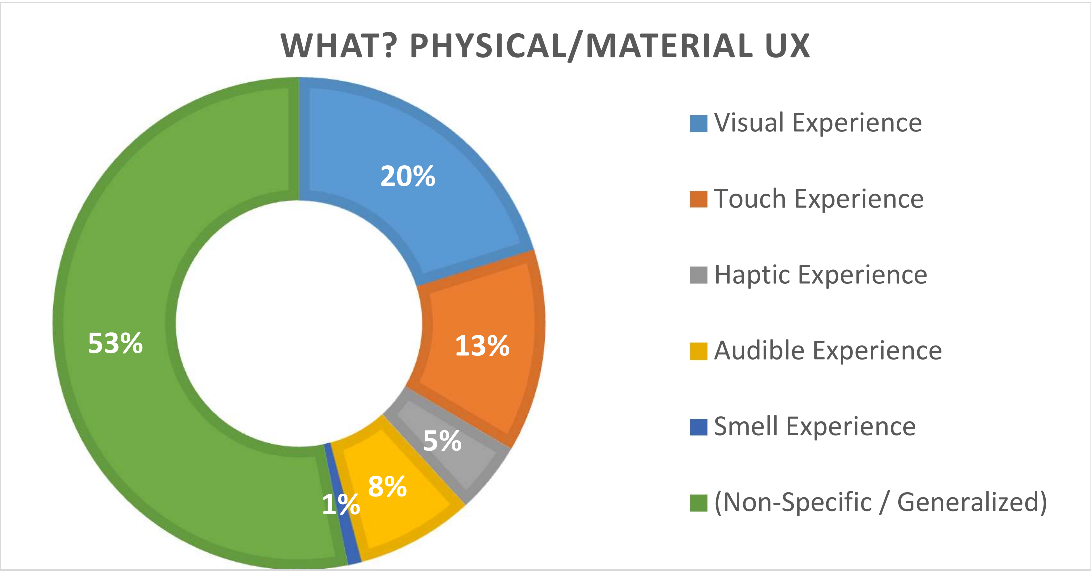

Figure 25. Classification of the user comments regarding the physical/material UX

On the other hand, the percentage of comments about the visual experience is higher than the others. As stated by Schifferstein and Spence (2007), generally visuality is the primary sense we use during interaction as it offers a lot of information about a product in the shortest time possible. For this reason, the comments relate mainly to the visual perception, which is followed by experience of touch that is generally related to material qualities and surface properties. Schifferstein and Spence (2007) takes touch similar to vision, as it also provides functional cues to the user in a short amount of time. In addition to its functional element, touch sensations also include an emotional component that is effective in terms of intimacy and product attachment (Schifferstein & Spence, 2007). These comments are followed in prevelance by audible experiences, which generally refer to audio commands, speech-based information provision, as well as warning sounds within the HMI. In addition to those, audible experience also includes the sounds of mechanisms and components in the car, such as the mechanical sound of a knob during turning or the click sound when pressing a button. These sounds occur as a consequence of their mechanical structure, materials and actions and are named as "consequential sounds" (Langeveld, van Egmond, Jansen, & Özcan, 2013). Haptic experience is the fourth most reported experience regarding the percentages of user comments. Even though some studies take surface qualities and even consequential sounds as a part of the haptic experience (Tietz 2008; Bernstein, Bader, Bengler & Künzner 2008; Enigk, Foehl & Wagner 2008; Maier 2008), in this study a separation has been made between touch as surface qualities (such as softness, temperature, texture) and haptics as active manipulation of controls (Pérez Ariza & Santís-Chaves, 2016) such as physical actions (i.e. force, resistance, vibrations), position (i.e. shape and position of hand and/or body) and dimensions (i.e. grasping, gripping). Participants' comments about haptic experiences are mainly about controls (i.e. thumbwheels, stalks, buttons) and actions as well as gesture-based interaction scenarios. Lastly, only one percent of the comments were about the olfactory qualities in the car, which are mainly based on the distinctive smell of leather that stays the same even after years and communicates quality and luxury.

5.4.2.3 Classification of the User Comments Regarding the Luxury UX

The final classification at this stage of the analysis was made based on the luxury values that were explained previously in the thesis in the 2.3.3 - Product Experience and Luxury Values section. The classification has four titles: (i) financial value (monetary aspects of products), (ii) functional value (how a product fulfils its function), (iii) symbolic value (meanings associated with luxury products) and (iv) experiential value (the experience that products offer to the user). The distribution of comments can be seen in Figure 26.

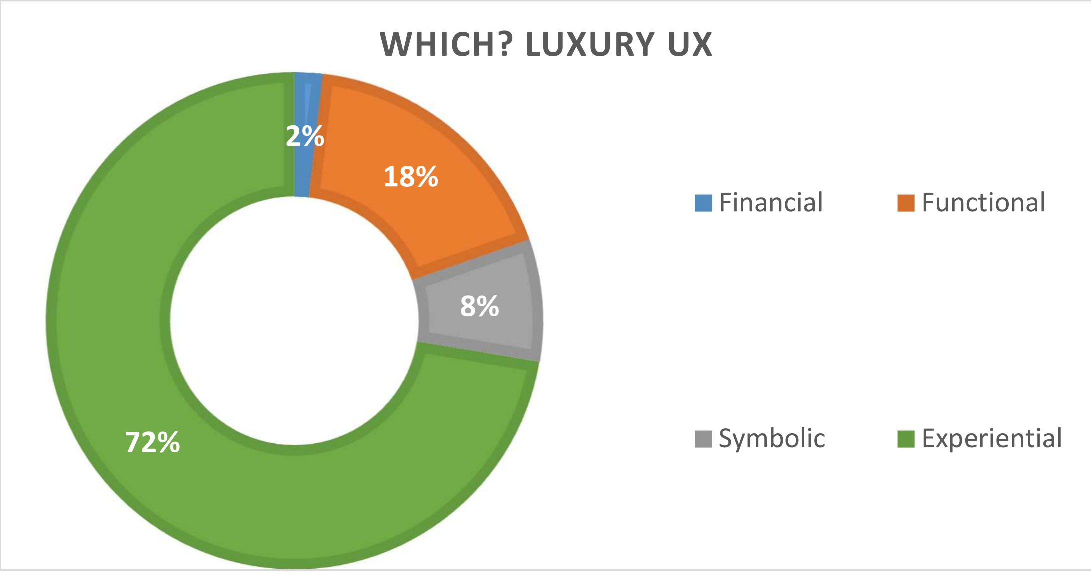

Figure 26. Classification of the user comments regarding the luxury UX

The comments related with monetary aspects are classified under financial value, such as the comment of participant 4 which is based on the expensiveness of leather or, participant 8 who focuses more on the investment made on the technology.

- *"**Leather is expensive** … and it is not something that you get in every car" (P4-02)*

- *"…. it's shows the **more investment in the technology** in the car…" (P8-16)*

In general terms, luxury has been discussed earlier as associated with the financial value of a product or the price that you need to pay to own that product. However, the findings of the field study here reveal the percentage of comments related to financial value is very low (2%). Regarding the fact that the research focus is on the luxury UX, rather than a broader discussion of luxury goods and their ownership, it can be an expected result that users tend to focus more on experiential value rather than financial value during their interviews. However, even in the first question of the interview *"Do you find anything luxury in your car?"*, participants tended to talk about the physical qualities rather than the monetary aspects of their cars.

Based on the percentages, symbolic value (8%) is the next represented component of luxury UX, which was essentially about the meanings that people associate with their products. The comments defining the symbolic value mainly depend on the comparative use of materials (rarity, novelty, uniqueness), use of technology (rarity, novelty), production techniques (mass-produced vs handmade), number of features (extras) or just the experience their car offers when considering other cars, especially in reference to cheaper or older models.

However, symbolic value can also be evoked by the brand identity and position. Symbolic value comments can be exemplified through participant 10's comment that associates black plastic with cheap cars and the impression of luxury as differentiation from cheaper car brands. Another example comment is from participant 16, focusing on leather as a material and how it gained the luxury meaning through the unique nature of that material.

> - *"I think it's because of an* ***impression that that's [sic] created by cheap cars less expensive cars being predominantly black plastic****, so the impression of luxury is that differentiation from cheaper cars cheaper brands" (P10-14)*

> - *"The fact it comes off the* ***back of an animal it's not readily available*** *for me suggests a* ***feeling of making it a little bit more different and a little bit more special and unique*** *than the mainstream vehicles" (P16-19)*

An object that does not function well cannot offer a luxurious experience. As a reflection on this, the functional value (18%) is the second most commented value among participants' interview answers. The comments on functionality were mainly based on the quality of components (e.g. size and resolution of screens), organisation of the interaction (e.g. the logic behind menu structures and controls, simplicity), added functionality through connectivity, and configurability supporting the functionality (organisation of interior elements). This can be exemplified by the comment of participant 20, which is similar to many other comments focusing on the main information provision area in most of the cars – the 'central screen' – and its performance, based on size and resolution. Another comment from the same participant was on the configurability and how it enhances the driving experience.

> - *"****Size of the screen*** *is luxury, performance,* ***resolution of the screen*** *when it's on" (P20-03)*

> - *"All* ***the configurability*** *I can have to set the combi up here when it's once set, I have got a profile that is me it's what I have done once" (P20-21)*

There are also other comments amongst the dataset related to functionality, which are about the design of the controls and how they can be easy to locate and use during driving, such as the comment of participant 23 or the comment of participant 25 explaining functionality and how accessible controls are through design and organisation of the HMI.

> - *"I think it's very good we got the new the big knob here (knob in the central console) which I find [sic], obviously when you're driving you need to something* ***it's quite easy and quite quick*** *to* ***instead of looking to a small button*** *on your dashboard you* ***got a***

great big knob here that you can find easily without taking your eyes off the road that is a real good idea" (P23-06)

*- "Yes, I like the fact that I have got the HMI screen. It is **very accessible** I have **got lots of functionality**" (P25-02)*

The experiential value (72%) is the most mentioned value amongst the comments of participants. The interview started with an open-ended question that asks *if they find anything luxury in their car, if so, what it is and why they find it luxury*. This question is open for interpretation and can be answered by focusing on any one of the four values. However, people tended to start with details that evoke emotions such as desire and what they like most about their car. Those responses were mainly about the experiential value that they get from their car. Furthermore, the initial open-ended question was followed by subsequent experience-oriented questions, which inevitably drive the results to become more related with experiential value. Participants defined experiential value through subjects ranging from physical comfort (location of controls and screens and how they contribute to their experience; *P23-01*) to smartness (to support their driving experience; *P21-25*) or from materials stimulating sensations (e.g. smells, textures and finishes; *P8-08*) to connectivity (to personal devices or applications; *P9-13*) providing a sense of relatedness with others. The example comments are as follows.

*- "I love this car, find the **seats really comfortable**, the dashboard I love" (P23-01)*

*- "They somehow know what **the right time is to intervene** ……" (P21-25)*

*- "On the gear stick and on the door trim and things like that I think it's **a nice feel, it gives a nice smell** inside the car" (P8-08)*

- "The only that isn't that [sic] I really like is the integration with such as WhatsApp for example I don't do text anymore at all so 0 text to send per month it's WhatsApp only" (P9-13)

Given the line of questioning, as expected more than half of the comments were about the experiential value (72%) rather than how the car functions, the financial value of the interiors or the symbolic value of the brands. UX as defined before (2.3.2 - Dimensions of User Experience) is about the sensory information we receive from products and the meanings and emotions they evoke in users. The reflection of this definition can be seen in most of the experiential value comments: how the physical embodiment is interpreted through sensorial information and how it is translated to the emotions and meanings attached to products.

The classification of the data according to interview stages, sensory modalities and luxury values were useful for revealing what people mostly talked about when they were defining the experience of luxury that may or may not already exist in their cars.

5.5 Data Analysis Round 2

In the previous process, the data had been classified, organised and filtered for qualitative analysis. The second analysis on the dataset, which was much larger in scope and more intensive in its application, involved *Content Analysis* (Krippendorff, 2004), defined as a systematic technique for reducing huge text datasets into fewer categories through 'coding'. Coding was experienced as a cyclic process, requiring the researcher to read data several times at consequent stages and to keep filtering and refining the codes and analysis. It comprised a qualitative data analysis strategy, which generally starts with applying an open coding (an initial organising and categorising of the data into meaningful chunks of words for generating categories, themes and concepts). Saldana (2009) defines a code as "a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data". Over the process of coding, new codes are created, and existing codes are refined, thus the coding process is evolutionary based on the actions and progress of the researcher.

The initial step for the coding was for the researcher to read the data over and over to familiarise with the comments and to understand the basic concepts and potential patterns amongst participants' responses. During the reading process, there were several codes and comments noted by the researcher for each comment. There were several concepts and patterns noted by the researcher that are simplified to keywords and concepts in the following process. The simplified codes were about how the luxury is achieved in car interiors however some codes cannot be summarised only as a keyword but required a second step that is the discussion points raised from those comments. For this reason, two additional columns were added to the dataset, and the simplified concepts and keywords transferred to the excel sheets (Table 4). The titles of the columns added were:

- HOW? ACHIEVING THE LUXURY; *Key concepts and features from the transcripts*
- OTHER COMMENTS; *Discussion points (additional comments) from the transcripts*

Participant / User Number	Raw Data Transcript	HOW? ACHIEVING LUXURY UX KEY CONCEPTS FROM TRANSCRIPT	OTHER COMMENTS DISCUSSION POINTS FROM TRANSCRIPT
U4-07	It is nice to have heating and the cooling in the seating as well so you sometimes leather during summer time it can get very hot so can keep the ventilation going on.	COMFORT	HEATING AND COOLING - FLOW OF TOUCH
U5-07	Starting within the car you know this sort of brushed finish that appears everywhere throughout the car and throughout the most of Audis.	MATERIALS	BRAND ASSOCIATIONS - CONSISTENCY IN TERMS OF SURFACE FINISH

Table 4. Examples of coded data

The spreadsheets were shared with the supervisors and it was agreed to choose two participants for a piloting of the coding process, to build an initial set of codes and to check the whole process prior to working with the remainder of the data. The comments of two participants are coded one-by-one by the researcher and an empty excel sheet shared with the primary supervisor to carry out a similar process independently. After the coding, all the codes and the notes have been compared for refinement and understanding the underlying motivations of the users through their statements. All of the codes have been discussed in detail to reach a consensus for suitable keywords. This process required several cycles of discussions to decide on keywords-codes to summarise participants' concepts without losing any valuable phrase. Coding of the two participants created a master list of codes and definitions that could be referred to during the whole coding process.

After the initial coding of the two participants and the discussions, the remainder of the data coded by the researcher with the help of the master list. However, as expected there were other comments that did not fit the codes in the master list, requiring new codes or revisions. For these comments, there were several other code suggestions (generally directly transferred to the list from the exact words of the participants) discussed with the supervisors through a series of meetings and e-mails. Therefore, this process was a generative process that revealed new codes, merged some of the codes, or revised or reworded existing codes to communicate the valuable fragments of the comments. For this reason, the master list was periodically updated, changed and became larger or smaller during the whole coding process. After each of the 700 lines had been coded and prepared with the excel sheet, the master list included a pool of 28 separate codes. Those were the initial codes that require refinements and revisions during the analysis process. The list of initial codes and definitions are summarised in the Table 5.

1	**LUXURY DEFINITIONS**	Interpretations of luxury	15	**PERSONALISATION**	Ability of car to tailor the experience to the personal needs and desires of the user
2	**COMFORT**	Physical ease, relaxation mainly about ergonomics	16	**MUSCLE MEMORY**	Keeping memory of specific motor tasks by repeating
3	**MATERIALS**	Materials affecting the experience of the user	17	**CONFIGURABILITY**	Use of native tools in the system to change its behaviour or features
4	**PHYSICAL QUALITY**	High quality of components and technologies	18	**CUSTOMISATION**	Ability of the car to offer options to create the desired experience
5	**EASE OF USE**	How easy the product to use	19	**ASSISTANCE**	Systems helping to driver for driving related activities
6	**FUNCTIONALITY**	Serving the purpose well	20	**SMARTNESS**	Ability to collect, process, and produce information
7	**CONNECTIVITY**	Capacity for the interconnection of platforms, systems, and applications	21	**EXCLUSIVITY**	Fashionable, stylish and exclusive properties of a car
8	**REALISATION**	Execution of the design assembly details of the components	22	**APPEARANCE**	Changing interior details with light, movement etc.
9	**RESPONSIVENESS**	How quick the system responses to the commands - physical and information	23	**FORM**	Styling details of the car
10	**READABILITY**	Readability of the text and icons around the physical controls	24	**ENGAGING UI**	Encouraging user to interact with the system
11	**AFFORDANCES**	Clues in car about how controls should be used	25	**TRENDS**	Users comments about interaction trends and examples of other products
12	**AUTOMATION**	Having the capability of starting, operating, moving, etc., independently	26	**GUI VS PHYSICAL CONTROLS**	The comparison between GUI and physical interaction
13	**RARITY**	Uncommon qualities of the car	27	**INTUITIVENESS**	Perceiving directly by intuition without rational thought
14	**EFFICACY**	Ability to produce desired interaction	28	**PERFORMANCE / DRIVING JOY**	Ability to provide driving joy through performance of the car

Table 5. Initial list of codes

To make the data set more understandable, the codes were classified according to their role – since each code referred to a different role in terms of design properties. Such as *rarity* and *trends* can become ***discussion points*** related to the meaning of luxury or future reflections, however, *comfort* and *ease of use* are about ***human factors***. Also, codes like *materials* and *form* are related to the ***physical embodiment*** of the car whereas codes such as *smartness* and *assistance* are related to the ***functions and features*** of a car. The classification of the codes can be seen in Table 6.

	COMFORT		
	EASE OF USE		
	RESPONSIVENESS		
	READABILITY		FUNCTIONALITY
	AFFORDANCES		CONNECTIVITY
	MUSCLE MEMORY		PERSONALISATION
LUXURY DEFINITIONS	INTUITIVENESS	REALISATION	CONFIGURABILITY
RARITY	ENGAGING UI	APPEARANCE	CUSTOMISATION
EXCLUSIVITY	GUI VS PHYSICAL CONTROLS	FORM	SMARTNESS
DESIGN CHARACTERISTICS	EFFICACY	MATERIALS	ASSISTANCE
TRENDS	PERFORMANCE-DRIVING JOY	PHYSICAL QUALITY	AUTOMATION
DISCUSSION POINTS	**HUMAN FACTORS**	**PHYSICAL EMBODIMENT**	**FUNCTIONS AND FEATURES**

Table 6. Classification of codes

This classification was very useful for understanding and grouping the codes and this process also revealed similarities and repetitions of codes and requirements for further refinement of all the codes. Because of the fact that we used ‘the exact expressions of the participants’ in order not to lose any meaning during this process, the number of codes was high, and their content and wordings differed from each other. The data processing that followed was intended to discuss the codes in detail to find out if there were any codes referring to similar concerns/concepts however worded differently. Several meetings were carried out with the research supervisor to reveal those codes and mutually agree whether to merge or reword some of them in line with the design terminology. During this process, the researcher and the supervisor discussed each code with the transcriptions one-by-one to identify the pertinent codes and reach a consensus on them. After this process, the refined code list included 17 codes (Table 7**Hata! Başvuru kaynağı bulunamadı.**).

The comments made by participants were not always positive. Some of the comments were explaining the desires and demands of users regarding the luxury, which may not currently be present in participants’ cars. Even though the interviews made reference to the interior details of their own cars, participants tended to also talk about other cars (the luxury details in other cars) or what else can be done to improve automotive 3I (trends and expectations) to achieve luxurious experience. The following process for the coding was to classify the data according to existing luxury details in peoples’ cars (coded as positive), the things they would like to have but do not have in their current car (coded as negative) and the trends or future reflections that they are talking about (coded as neutral). Numbers of positive, negative and neutral comments were showing the design details already achieved by their cars (positive) or by other cars (negative) and future possibilities and technologies that they would like to have (neutral). The percentages of positive, negative and neutral codes will be discussed in detail at the end of this section and the following section (5.6 - Results Round 2) after all the codes are refined and edited as the final list of codes.

EASE OF USE	COMFORT	MATERIALS	INTUITIVENESS	FUNCTIONALITY	REALISATION	CUSTOMISATION	RARITY	PHYSICAL QUALITY	LUXURY DEFINITIONS	FORM	SMARTNESS	CONNECTIVITY	EXCLUSIVITY	AUTOMATION	APPEARANCE	TRENDS	PARTICIPANTS
✓	✓	✓		✓				✓	✓			✓					**P1**
✓		✓		✓	✓			✓									**P2**
		✓		✓			✓					✓		✓			**P3**
✓	✓	✓				✓	✓						✓	✓			**P4**
✓		✓	✓		✓				✓				✓		✓		**P5**
	✓	✓		✓	✓					✓							**P6**
✓	✓	✓	✓	✓		✓	✓							✓			**P7**
✓	✓	✓	✓		✓	✓		✓				✓	✓			✓	**P8**
✓	✓		✓			✓		✓				✓				✓	**P9**
		✓	✓		✓	✓	✓	✓									**P10**
✓	✓			✓			✓	✓									**P11**
✓	✓	✓	✓		✓	✓	✓					✓	✓				**P12**
✓	✓	✓		✓	✓		✓	✓		✓			✓				**P13**
✓	✓	✓	✓	✓	✓	✓						✓			✓		**P14**
✓		✓	✓	✓	✓								✓	✓			**P15**
✓	✓	✓	✓		✓		✓	✓	✓		✓		✓				**P16**
✓	✓		✓	✓		✓	✓		✓	✓				✓		✓	**P17**
✓	✓	✓		✓	✓			✓	✓								**P18**
✓		✓	✓		✓				✓		✓						**P19**
✓	✓	✓	✓			✓	✓	✓	✓	✓	✓					✓	**P20**
✓	✓		✓	✓		✓			✓		✓				✓		**P21**
✓	✓	✓	✓	✓		✓	✓		✓	✓	✓			✓		✓	**P22**
✓	✓	✓	✓		✓					✓	✓	✓			✓		**P23**
✓	✓		✓	✓		✓			✓	✓		✓					**P24**
✓	✓		✓	✓		✓			✓	✓	✓	✓			✓		**P25**
✓	✓		✓		✓						✓			✓			**P26**
		✓	✓			✓				✓	✓				✓		**P27**
✓	✓			✓	✓	✓		✓							✓		**P28**
24	**21**	**20**	**19**	**16**	**15**	**15**	**11**	**11**	**11**	**9**	**9**	**9**	**7**	**7**	**7**	**5**	**#**
86%	**75%**	**71%**	**68%**	**57%**	**54%**	**54%**	**39%**	**39%**	**39%**	**32%**	**32%**	**32%**	**25%**	**25%**	**25%**	**18%**	**%**

Table 7. Number (#) and percentage (%) of participants mentioning codes

The mention times of codes were useful for understanding the main issues that participants talked about. However, the challenge was to identify how many participants were talking about the same issue, since some participants were more talkative than others and this might change the mention times of the codes and distort the data. For example, in raw data, '*trends*' code was mentioned 15 times, which is more than '*exclusivity*' which was mentioned 12 times. However, the number of individual participants talking about '*trends*' was 5, whereas 7 participants talked about '*exclusivity*'. Therefore, '*exclusivity*' becomes more mentioned in terms of the number of people talking about it. There are many other examples within the data set that are mentioned by only one or two persons however coded in more than one sentence. In order not to let talkative participants' comments to distort the data the number and percentage of the participants mentioning the codes were calculated and presented in rank order, as in Table 7**Hata! Başvuru kaynağı bulunamadı.**.

According to Table 7**Hata! Başvuru kaynağı bulunamadı.**, some of the codes such as *exclusivity, automation, appearance and trends* are quite low based on the percentage (25% or fewer) of participants talking about them. This led us to go through the data set once again to see if there were possibilities to merge some of the comments labelled with these codes into more prominently mentioned codes on the basis of being sub-concepts. This was so as not to cause confusion in readers' minds. To achieve this, a further intense process of going through the dataset one more time was needed.

At this stage of the data analysis the Excel sheets and computer screens did not provide an effective medium to discuss the details of multiple codes and comments simultaneously. For further discussions and organisation, we choose *smartness* as an initial discussion point to find out how to organise the data. *Smartness* had a relatively small pool of comments (16 comments, 9 individual participants) which made it relatively easier to write-down and organise as a starting point for the process. All the comments coded as *smartness* were handwritten on post-it papers one-by-one to have the flexibility to quickly reorganise and reappraise them by sticking them under different headings/sub-headings during the organisation process. The comments were organised on an A3 paper (Figure 27), which revealed groups and patterns, named as sub-headings under the general classification heading of *smartness*.

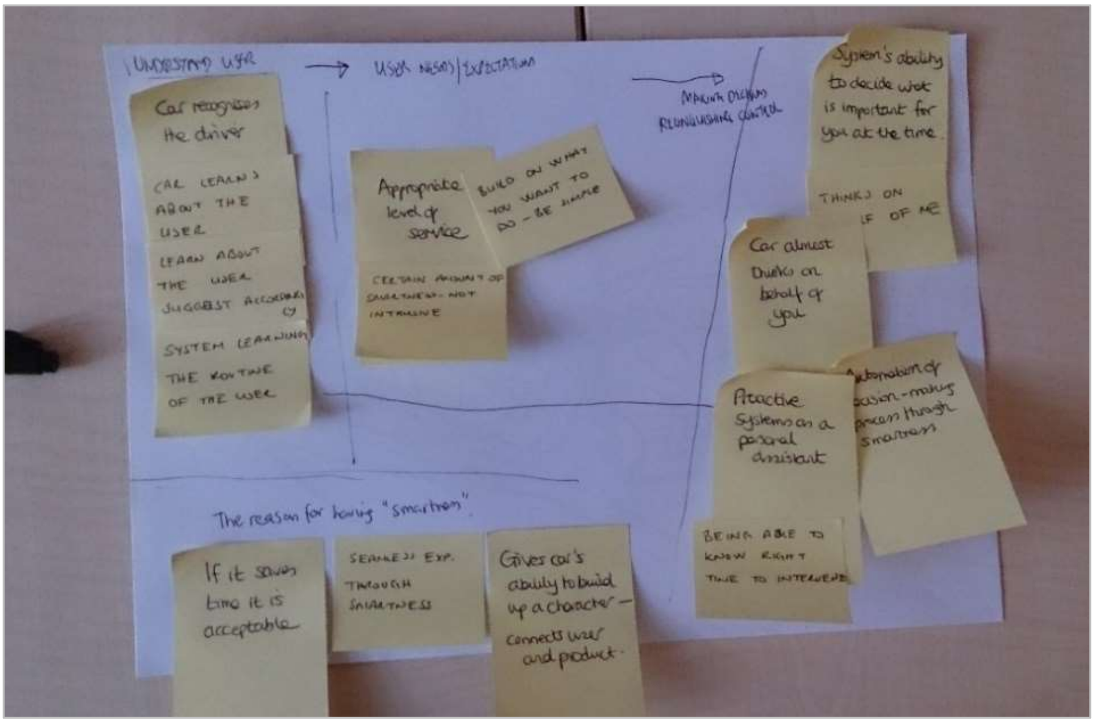

Figure 27. Organisation of smartness comments

The initial study of the organisation of *smartness* led us (the researcher in consultation with the supervisor) to carry out a similar process for each heading to reveal the similarities, differences and patterns in between them. To facilitate this process, the comments were printed out, cut and prepared as small cards suitable for quick rearrangement. The cards included the comments and were colour-coded as green for positive, grey for neutral and pink for negative. Cards for each and every heading and comment were printed, cut and prepared for the organisation. In addition to the printed cards, there were large-sized papers (A1, A2 or A3s) to be used as the canvas for the organisation of the comments and reusable adhesives (tack-it) provided the flexibility of post-it papers to move, organise and fix the position of the comments multiple times until a final arrangement was agreed upon.

At times when we moved the comments within the canvas to classify and reconsider their position, it was necessary to revisit the final code list and make some adjustments. Therefore, the discussions changed the final code list as well as the associated position of the comments. For this reason, the Excel sheets were updated simultaneously, and all the updates were reflected on the graphics automatically during the process in order not to lose any data. An example of the organised comments for *Ease of Use* can be seen in Figure 28.

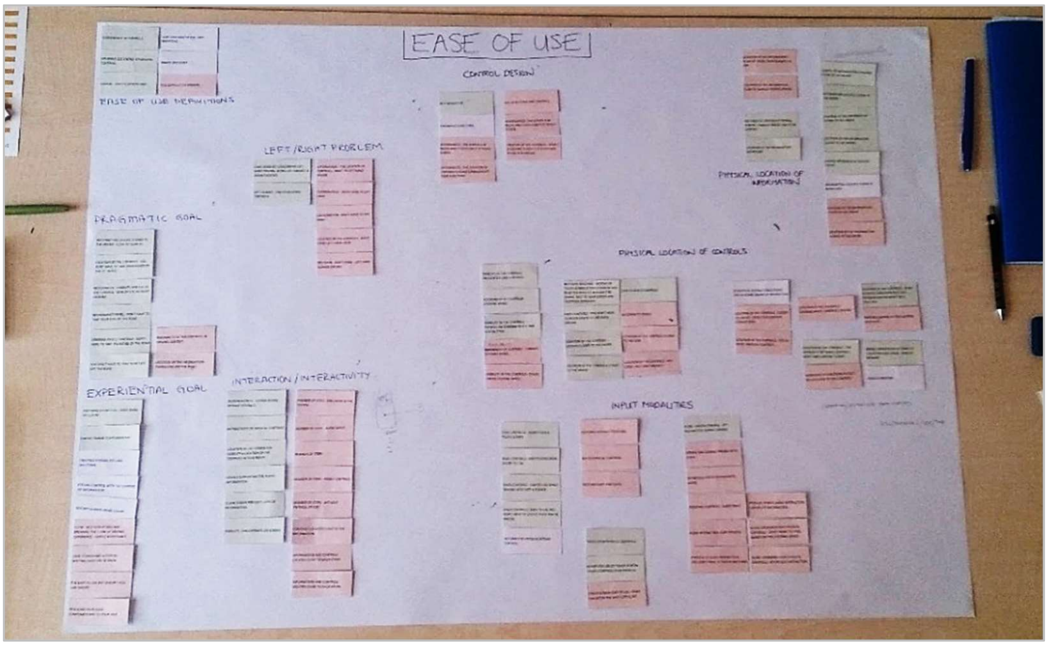

Figure 28. Example of organised comments (ease of use)

The discussions also helped us comprehend the entirety of the classified data set in front of us, to move coded data recurrently, and then to verify their coding against the final code list. The codes analysed with the comments revealed the similarities in between them. For example, *rarity* and *exclusivity* are two concepts that are supporting each other and very close in terms of meaning. Moreover, those two concepts are about the *definitions of luxury* which was a title by itself within the initial code list. For this reason, we decided to merge those codes under the *luxury UX* title and include the *rarity, exclusivity* and *luxury definitions* as sub-concepts for this main title. Another example is *intuitiveness,* which is related to *ease of use* in general and also supports the *comfort* title. For this reason, we have gone through the comments of users coded under *intuitiveness* and distributed those comments under *ease of use and comfort*. *Physical quality* was another title that was distributed to other titles, as it is generally communicated through *materials and realisation* the details in the car. Similar to *physical quality, appearance* which was referring to changing interior elements, also related with the *form, realisation* and sometimes *materials.* We have distributed the comments about *appearance and physical quality* to the relevant groups under the *physical embodiment* cluster. *Automation* used to be a group by itself, but it is actually one of the properties of smart products which led us to transfer all comments about *automation* to *smartness*. Finally, f*unctionality* was a large group; however, it was also related to several other groups for example, it supports *ease of use* and also *comfort*, it can be supported by *smartness, connectivity or customisation* and also it might be about the *trends* as future reflections on car. This was causing misunderstandings – as a result, we decided to distribute those comments to suitable headings. After all the organisation processes per heading were complete, the physical canvases with the comment cards were digitally reproduced as in Figure 29**Hata! Başvuru kaynağı bulunamadı.**. This was especially so as not to lose the data and organization. In the end, there were 10 canvases (one for each remaining heading) that were produced physically and digitally.

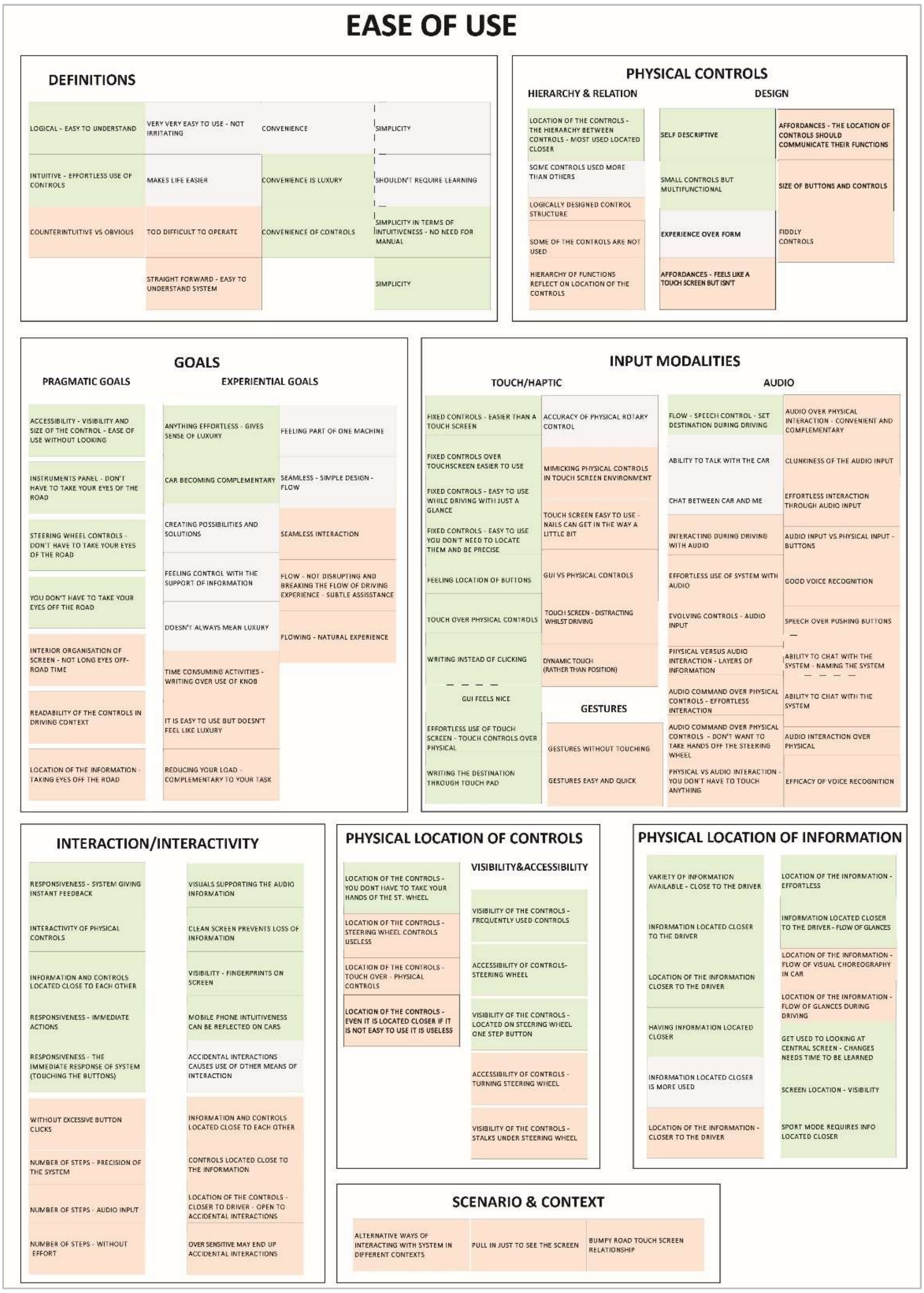

Figure 29. Classification of Ease of Use comments – recreated in digital format

As a result of this final refinement and filtering process, the number of top-level codes that we have was 10, which are themselves classified under four top-level classifications *discussion points, human factors, functions and features* or *physical embodiment* clusters. The final codes, the number of comments, and the number and percentage of participants are listed in Table 8. The table presents the data based on rank order of percentage of participants offering comments per code. However, the first and last codes (Luxury UX, Trends) were treated differently since they did not fall into the four top-level classifications. Instead, Luxury UX was considered to catch miscellaneous comments related to the concept of luxury experience, whereas Trends was considered to relate to design and technology changes that are influential on next generation products and services and which would form a 'bridge' to tangible solutions for new in-car HMI.

CODES	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12	U13	U14	U15	U16	U17	U18	U19	U20	U21	U22	U23	U24	U25	U26	U27	U28	#	%
LUXURY UX	5	0	1	3	1	4	2	4	0	2	2	1	6	3	3	8	18	10	0	8	14	4	0	2	5	0	0	2	**22**	79%
EASE OF USE	1	5	2	0	2	0	9	4	7	1	7	2	6	4	7	4	15	5	6	7	13	17	8	11	5	2	0	3	**25**	89%
REALISATION	1	3	0	0	2	8	0	3	1	3	0	1	2	3	4	6	0	1	1	1	0	1	1	0	1	1	2	2	**21**	75%
MATERIALS	2	4	4	5	6	2	1	12	0	7	0	6	5	2	1	17	0	5	12	5	1	0	1	0	0	0	0	0	**19**	68%
COMFORT	3	1	0	2	2	5	5	0	3	0	3	0	3	7	0	4	4	9	0	0	0	3	2	3	0	2	0	1	**18**	64%
SMARTNESS	0	0	1	6	0	0	2	0	0	0	0	1	0	1	0	2	2	2	1	6	3	4	1	0	3	4	5	0	**16**	57%
CUSTOMISATION	0	0	0	2	0	0	1	1	0	5	0	2	1	4	0	0	2	0	0	3	3	3	1	5	5	0	6	12	**16**	57%
FORM	0	0	0	0	0	5	0	3	0	0	1	0	1	0	0	0	0	2	0	4	0	1	1	2	2	0	3	2	**12**	43%
CONNECTIVITY	1	0	1	0	0	0	0	1	7	0	0	1	0	1	0	0	0	0	0	0	0	2	1	3	4	0	0	0	**10**	36%
TRENDS	1	0	0	0	0	0	0	4	4	1	0	1	0	1	1	0	4	0	1	5	1	1	0	0	0	0	1	0	**13**	46%

Table 8. Final code list and number (#), percentage (%) of participants mentioning codes

Finally, a similar process was applied to the positive, negative and neutral information within the data set, to prevent the distortion of data through talkative participants. The percentages of all the codes regarding their positivity, negativity or neutrality were calculated participant-by-participant and this revealed definitive percentages for all the codes, listed in Table 9.

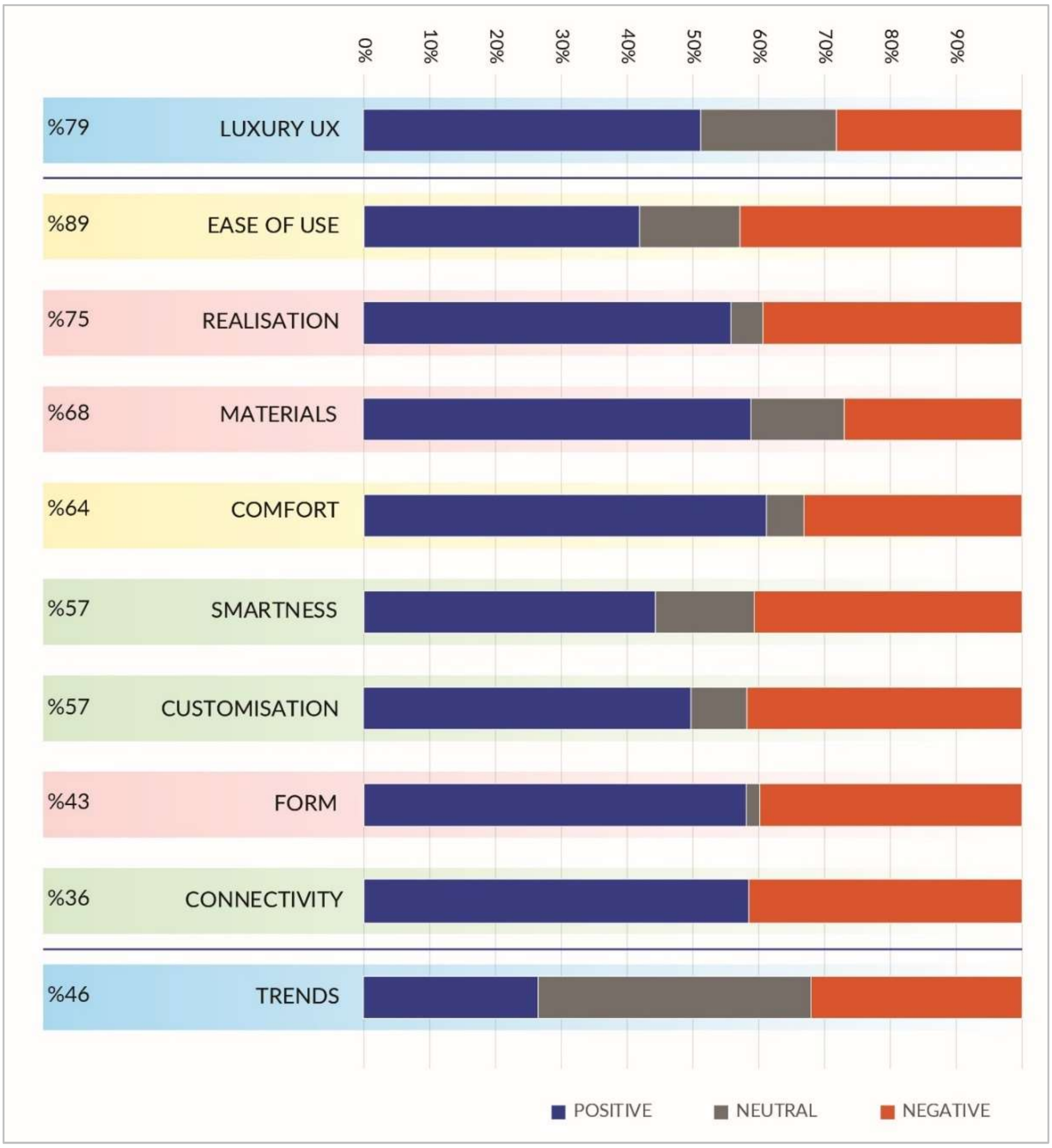

Table 9. Percentages of positivity, negativity and neutrality of participants' comments

This section was mainly about the process of analysis of the large dataset and the initial results were mainly on the classification and refinement of the codes. It included quantitative results that usefully summarised the 'big picture' in relation to the general topics captured within the interviews. The following section focuses on explaining the details behind each of these ten codes, and how they relate to the car interiors by using exemplars of the comments of participants.

5.6 Results Round 2

After the intense and cyclic process of coding and organising the large data set, the final cluster set consisted of 10 codes that are classified under descriptive headings. The classification includes; (i) human factors, containing ‘ease of use’ and ‘comfort’, (ii) physical embodiment, containing ‘realisation’, ‘materials’ and ‘form’, (iii) functions and features, containing ‘smartness’, ‘customisation’, and ‘connectivity’, and finally - different from the others - (iv) discussion points, separated as ‘luxury UX’ and ‘trends’. All clusters and headings are related and effective within each other, however the discussion points are mainly about the experiential details and trends that might drive the luxury sector. The luxury UX is about the interpretations of participants in their car regarding the luxury details and it would be useful to start with the details of luxury UX heading for understanding their viewpoints and definitions of luxury. The details of all these clusters, headings and subheadings will be explained in the following sections, starting with the luxury UX heading.

5.6.1 Luxury UX

The main motivations of drivers to purchase luxury cars can be identified as the performance (P16, P20) they offer, which in turn supports exclusive experiences. The performance is about “what happens under the pedal” (P16) and “use of skills” (P20) while handling a car, creating a whole experience through the communication between the driver and the car. However, the HMI system can become a distraction (P20) or frustration which can ruin the driver-car relationship. The luxury HMI should have the ability to become invisible (P16) when it is not needed and only complementary for the intended driving experience.

The definitions of luxury within the literature have been discussed in section 2.1 - The Concept of Luxury and the luxurious driving experience is defined by participants through their experiential and pragmatic goals. The experience is defined by participants initially as “welcoming” (P8), where the car welcomes you with its comfort details (seating, heating etc.) and design. Then during driving through the assistance and support it provides exclusivity, making you feel like “winning - saving time” (P18). This way it can offer you “a calm and relaxed environment” (P21) and this can be maintained by keeping the flow with the “sense of progress” (P21). The sense of progress can easily be broken by traffic jams with start-and-stop cycles and in these situations “driving longer instead of sitting in traffic” (P21) can become preferable and achievable through smart applications. This also supports the sense of control as "being the person who decides what to do" (P21), "being in control" (P18, P21, P25), and having a state of awareness about everything happening in and around the car (P21, P25). However, this sense of control and decision-making process requires additional information and support by the car by offering the driver choices and information about the results (P21). With the provided information and time, the driver can make his/her own decisions (P18) instead of feeling useless and bored (P21) through automation.

As stated before, luxury is about feeling special (P5, P8) and being served by the car (P14, P15, P21) such as "a butler" (P15), "a concierge" (P14) or "an invisible waiter" (P21) that can understand your needs and act as subtle as possible that you will not even realise. As in the example of invisible waiter the amount of service is quite important, which might otherwise end up with a car patronising oneself. Therefore, an "appropriate level of service" (P20) is the key for a luxurious experience. Finally, harmony and consistency can be used as terms to summarise the key design elements to keep luxury. The harmony between the "materials and form" (P20), "production techniques and styling" (P6) can provide luxury. In addition to harmony "the consistency within the brand throughout years" (P25) in terms of design decisions (locations, textures, controls and actions) sets up a muscle memory on users and maintains the luxury feeling for years. The definitions of participants and elements to provide and maintain luxury user experiences are summarised in Figure 30**Hata! Başvuru kaynağı bulunamadı.**.

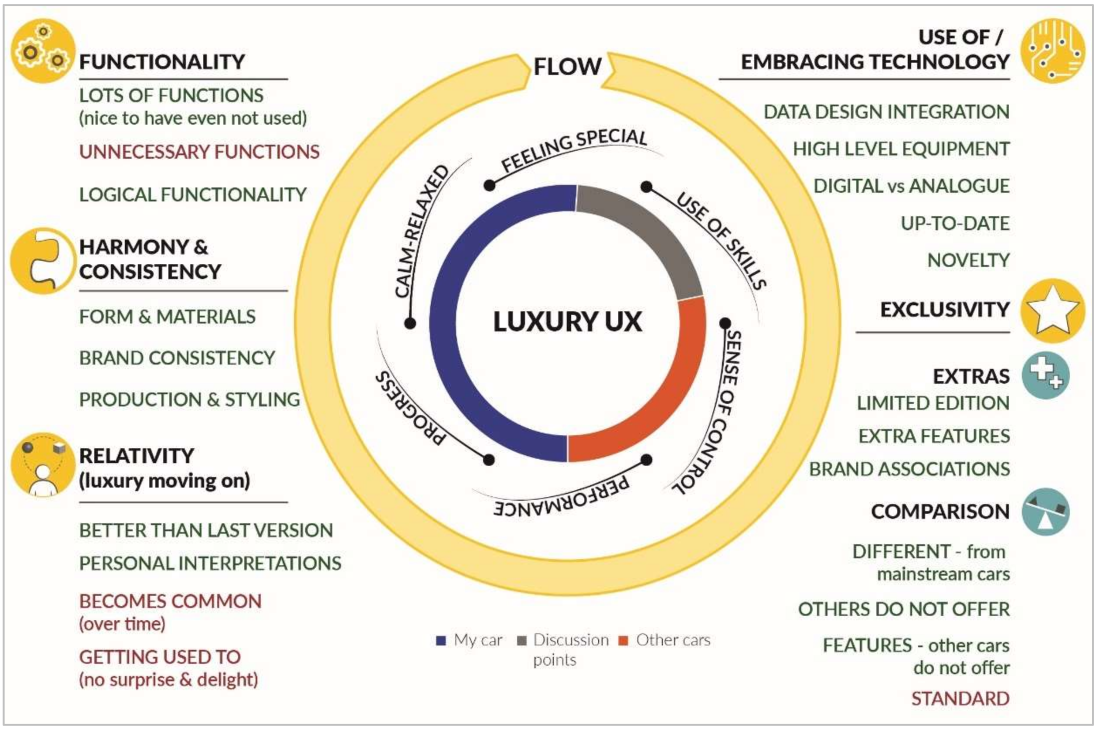

Figure 30. Luxury UX (graphical summary of comments)

As aforementioned (2.1 - The Concept of Luxury), luxury is not defined concretely because of the relativity of the concept changing through time and today with the democratisation of luxury it changes even on individual levels. The participants emphasized the relativity of the term, such as the luxuriousness of your car depends on how you define luxury (P1). The definitions might vary according to the age of the person such as “young people probably would ask for the latest trends” (P16). It might also be about the experience of the person, since people tend to compare their cars with the previous ones as in the comment of participant 17 “the nicest car I had until now” or participant 15 saying “better than the previous one”. It is also important to consider the effect of time on luxury; you might find your car luxurious at the time you have purchased however people get used to and start to take things for granted and “the surprise and delight” (P18) effect vanishes through time. Especially products including technology can become outdated easily and lose their novelty (P18, P20), moreover, the technologies could become widespread in time and no longer “rare” (P17, P18, P20). The relativity is about people, their previous experience and also other products: people can find their cars luxury or not luxury “compared to others” (P20, P24).

The comparison of one’s own car with others brings a feeling of exclusivity. The details such as “use of leather” (P4) with “its original smell” (P16) and rarity (P16) that it is not offered in mainstream cars supports the exclusive feeling in the driver. The exclusivity is not only about the comparison but also about the personalisation and rarity such as the “limited edition interiors” (P13), which are accessible by only a few consumers. In addition to limited editions there are also functions and features such as “time-saving features and applications (e.g. navigation)” (P18) already built-in luxury cars “different from standard cars” (P3, P10, P13) whereas others need to pay extras to access these features (P4, P7, P11, P17). The exclusivity is like “offering something different from others” (P10) more than standard cars. In summary others’ luxury (extra features, services, materials etc.) is already standard in luxury cars.

The functions and standards are quite determinant in positioning the products in users’ minds as the variety of standard functions in a car can communicate the exclusivity and rarity. “The extra features and functionality even though they are not used” (P7, P15, P17, P24) are nice to have and support the feeling of luxuriousness. Even though the functionality can become “overdone” (P17) with unnecessary features, it can also become quite supportive and assistive in certain scenarios. Moreover, sometimes we do not even realise we need that support and assistance until we use those functions (P28). Such as “the navigation” (P17, P18, P28) can become quite crucial and effective in certain conditions providing the feeling of being serviced by the car. Even though the functions can support the feeling of luxury they can also easily break this feeling if "they do not work correctly" (P1). The base of luxury is "having basic things right and working then looking for the icing on the cake" (P18) however having basic things without the "icing on the cake" (P18) could make a car "utilitarian but not flashy" (P17) and not luxury (P14, P17, P18, P22). A high quantity of functions can be desirable but "does not always mean luxury" (P6) they can easily become distracting (P17) and unnecessary in time. For example, the analogue dials (P6) are still used for communicating luxury however the digitalisation of things in cars offering more possibilities and support that could provide a more luxurious experience. Also, the buttons and knobs can also become unnecessary (P6) in time by embedding technologies such as the audio command or gestural interaction into cars. The logic behind functionality (P17), the support it offers and the distraction it may cause are the main things to consider for adding more features in a car.

Technology with a variety of choices and opportunities can be used as a means of communicating luxury and support a luxurious feeling. The communication of luxury has traditionally been through materials, craftsmanship, unique physical design and precision of the mechanisms but today this tradition is challenged by technology. However, this challenge can easily be turned into an opportunity by reflecting the "detailed thinking" (P8) and "refined design details" (P20) on the interaction. In addition to thorough planning and design process, technology requires "investment for improvement" (P25) as well as "investment for staying up-to-date" (P13). "Novel" (P12, P17, P25) and "rare" (P4) technologies can communicate the relativity and exclusivity of luxury. However, the use of technology is not enough by itself if it is not backed with data (P17) through research as it can end up with unnecessary functionality. Also, the quality of components as "high-end" (P8), "upscale, high powered" (P22) are important to maintain the performance throughout years. Luxury can be about but not limited to "having the best system" (P21, P22), it also needs to maintain its position through updates and "strong vision backed with data" (P17). Technology can easily become out-dated regarding the difference between "software lifetime and car lifetime" (P1) and "out-dated technology is not luxury anymore" (P13, P25). Technology trends (digitalisation (P10), smartness (P22)) can support luxury experience by offering time-saving assistance (P23) and ease of use to the drivers. Use of technology can create, maintain and update the ways of communicating luxury.

Luxury is relative from person to person depending on the experience, income, age, technology readiness etc. of them. However, the feeling of exclusivity is offering luxury for sure, through differentiating yourself from others which might be achieved by personalisation or maintained by customisation and supported with technology. All these definitions also depend on the harmony and consistency within the brand and designed interior itself and interaction. Even though the physical embodiment and material details in luxury cars offer people luxury experience throughout the years, they also need to explore ways of creating harmony between these details and technology as well as consistency within the use of technology. The definitions of users also refer to specific clusters which will be discussed in the following sections starting with the human factors cluster.

5.6.2 'Human Factors' Cluster

Participants comments on the human factors cluster are classified under two headings; ease of use and comfort. Ease of use (25) was the most commented heading and about 89% of the participants mentioned details about ease of use. Ease of use was the largest data set including comments about (i) physical controls (hierarchy & relation, design and location) that is all about the control properties affecting the experience, (ii) input modalities (touch & haptics, gestures and audio) general comparison of different modalities for in car interaction, (iii) information and how information affects the way we interact with the system (iv) interaction and interactivity (responsiveness, visibility, accidental interactions, number of steps) of the whole HMI system.

Comfort (18) ranked as the fourth most mentioned code with 64% percent of participants talking about it. The comments about comfort were mainly about the physical ergonomics that focus on the (i) scenario and the context (length of the journey and social experience) details to consider for designers, (ii) seats and (iii) steering wheel as the main comfort elements, (iv) physical effort to achieve certain tasks, (v) the left/right problem that is use of left hand or right hand for interaction (especially in UK, Ireland etc.) (vi) environmental (temperature, interior) organisation that supports luxury and (vii) reach & position as the requirements for physical ergonomics. The details of this cluster and headings are explained in the following section.

5.6.2.1 Ease of Use

Ease of use (Figure 31) can be defined with several components depending on the characteristics of the products as one of the important determinants for people during the decision-making process (Mack & Sharples, 2009). The definition can be made through the meaning of the word 'ease' that is freedom from great effort (Davis, 1989) as effortless use of design elements. Ease of use is generally the primary goal of design however there are also other examples which are intentionally not easy to use such as the examples of Donald Norman (2013) security systems, dangerous equipment, systems requiring proficiency etc. or games that are challenging by their nature. Moreover, the products can offer indirect experiences to the users in which case also the ease of use becomes supportive of the aimed experience (Hull & Reid, 2003). For example, in some of the automobiles the ease of use is not the main focus but the grand tour experience however effortless use of elements in car supports the focus on the experience.

Some of the participants defined the ease of use with the traditional definitions as “straightforward” (P25) “logical – easy to understand” (P7) or “should not require learning” (P10) “no need for manual” (P25). The traditional definitions are aiming at the pragmatic goal of ease of use such as the ability to keep your eyes on the road when interacting with the system (P2, P15, P18, P19, P23). However, “the convenience of controls” (P7, P26) that is “making life easier” (P11) can be interpreted as the supportive role of ease of use to the aimed experience. The ease of use “does not always mean luxury” (P5, P6) also the system should become “complementary” (P20, P23) that is supporting your task (P20), reducing your load (P23), making the time-consuming activities easier (P9) providing possibilities and solutions through information (P21). The ultimate aim for ease of use to contribute luxury feeling is providing a “seamless” (P17) “flowing” (P16, P17, P20) and “natural” (P20) interaction with “subtle assistance” (P16) as “feeling part of one machine” (P16). Ease of use definitions and subcategories are summarised in Figure 31.

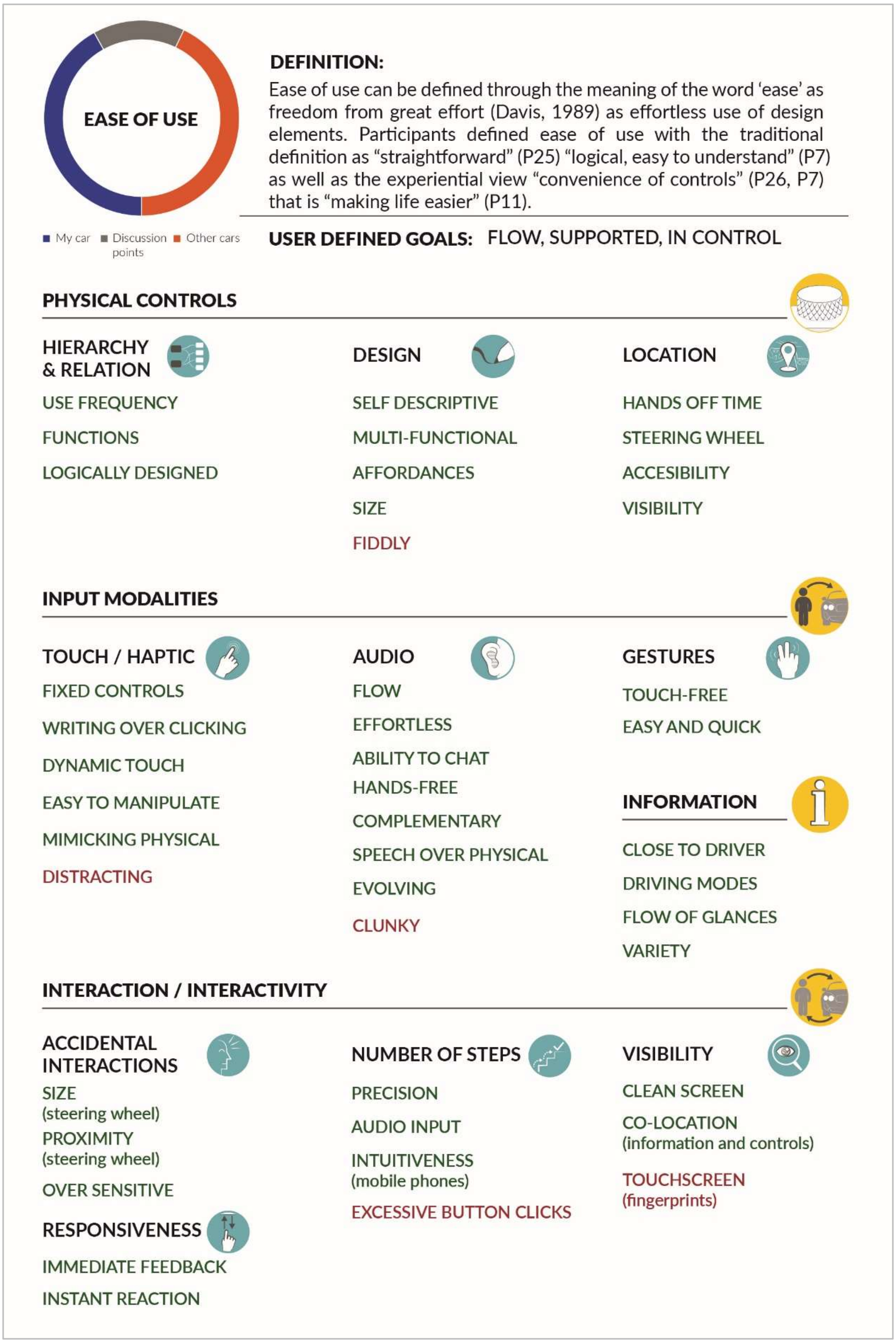

Figure 31. Ease of Use (graphical summary of comments)

The participants' comments regarding the ease of use were mainly about the dashboard controls, information and interactivity. The physical controls were the main interaction medium in cars, and they are still dominant regarding the in-car interaction however the hierarchy and relation in between the controls keep evolving. It is obvious that some of the controls are used more frequently than others and some are not even used (P17) such as door unlock used regularly (P17) however you set the date and clock once (P17). The use frequency of controls can be reflected on the hierarchy in the design of these controls (P22) such as the most used controls might be located closer to the driver. The functions of the controls are also another determinant that affects the decision on the location of them such as the functions related with safety requiring instant action or most used functions such as navigation requiring constant attention can be located within the immediate reach of the driver (P7). Therefore, the organisation and design of these controls require a 'logical base' and the hierarchy and relationship between these controls and functions include the facts to consider for that logical background (P7, P17). The organisation of controls can also cause the driver to keep their hands busy and away from the steering wheel. Regarding this fact there are also controls located on the steering wheel aiming for instant access and less distraction. The steering wheel controls are found easy to use by some of the participants providing that you do not have to take your eyes off the road (P19) or hands off the steering wheel (P22). However, some finds that controls are useless because they are ill-designed (P24) and not easy to use even though they are located close to the driver. Since the ill-designed details (such as size, location within the steering wheel) are open to accidental interactions the location does not matter, they become annoying and difficult to use (P24). Another issue about the location of the controls is about their accessibility, the steering wheel controls are assumed to be easy to use as they are easily accessible (P22, P23, P25). The stalks can also be interpreted as located close to the driver however they are not considered to be easy to interact with (P22) as they are blocked by the steering wheel and not visible or accessible. Regarding the location of the controls, the location should be taken as a 3D environment and in relation with others. The steering wheel is the first layer in terms of location and the stalks can be considered as the second layer which can be blocked by the steering wheel from time to time making them hard to understand and interact with.

In addition to the organisation and location of the controls also the design details are crucial in terms of the ease of use. There are several controls and control types in cars designed with different concerns. The main issue to consider while designing for ease of use is to make these controls "self-descriptive" that can clearly communicate their actions and results (P14). For being self-descriptive one of the important issues to consider is the affordances (P2) such as a screen can be perceived as touch screen just because it is within the immediate reach of the driver. However, even within the reach of the driver the screens might be just displays to provide information that can be understood through a trial and error period. In addition to that, car interiors include several small sized but multifunctional controls such as thumbwheel that can be turned as well as pushed like a button. Even though they offer the advantage of controlling several things with one small button, the logic and design details are crucial which could make them easy or difficult to use (P7). The small multifunctional controls especially on the steering wheel can be perceived as useful if designed carefully however if they are located on the central console, they become frustrating. The controls on central console demand visual attention especially if they are small sized and located side by side, they become hard to use and locate especially during challenging driving conditions (P11). Lastly, the shape and location of the controls could make them "fiddly" (P22) which require attention and skills in an annoying way. The physical controls even though studied for years still require further issues to consider with the new technologies especially aiming for a luxurious experience. The support of ease of use regarding the controls can provide a delightful experience however it can also ruin or disrupt the experience if not considered well enough.

Physical controls are still the main controls within car industry used for interaction however new technologies offer other types of input or develop the existing input types with the support of other modalities. For example, even though the touch screens offer effortless interaction they can become hard to use as they do not provide haptic feedback to the user. Moreover, their flexibility in terms of location of controls within the screen-based interface might become confusing from time to time requiring constant visual attention. For this reason, the interaction with these screens is generally carried to central controls such as large multifunctional knobs. These knobs are considered to be easier to use compared to the touch screens by some participants (P21, P25) as they are easy to locate just with a glance (P21, P25) and they do not require precision (P21) whereas touch screens can become distracting whilst driving (P17). The accuracy of these controls and their haptic and audio feedback make them preferable in certain conditions such as the rotary knob is found quite accurate in comparison to a slider on the screen (P8) for volume settings. However, some finds touch screens easy and effortless (P24) to interact if they are well-considered in terms of their location and design of their content (P8, P24). In addition to touch screens, the touch-based controls such as touchpads or touch-sensitive surfaces are becoming preferable (depending on their precision and responsiveness) as they offer an intuitive way of text entry as writing on a paper, such as the address entry into navigation system (P5, P9). Touch screens have some advantages (visual flexibility, effortless interaction) and disadvantages (control accuracy, lack of feedback, constant visual attention) that could make them luxurious or disappointing. In order to make touch screens and touch-based controls luxurious the input and output of physical controls can be "mimicked in touch environment" (P8) or "dynamic touch (3D interaction through pressure) rather than just position" can be used to support the experience (P13).

In addition to touch-based controls there are also touch-free scenarios that participants talked about the gestural and audio interaction. Gestures are studied for a long time however in terms of application they are still not that popular in automobiles except a few examples. Use of the gestures is perceived as quick and effortless (P9) in comparison to the physical controls and button clicks as they offer one step interaction similar to shortcuts. However, the touch-free scenarios that participants are talking about mainly depend on the audio interaction as it is widespread in comparison to other modalities. Participants would like to "chat with their cars" (P15, P14, P19, P20) so that they can have an intuitive interaction with their cars as they chat with people. This would provide a "flowing experience" (P9) through "effortless interaction" (P11, P19, P26) removing "the layers of information" (P25) with "touch-free interaction" (P15, P19, P20, P22). The touch-free scenario would be "convenient and complementary" (P20) depending on the "efficacy of voice recognition" (P11, P17) especially whilst driving for functions requiring constant attention such as navigation (P9, P11). Most of the participants are using audio input in their cars occasionally especially for phone calls and navigation functions. Still, the audio input is perceived as "clunky" (P22) with several steps and misunderstandings (unintuitive wording, accents etc.) which causes participants to choose other ways of interaction over audio (P11). However, smartness would make the system more intuitive encouraging to set up a language between the driver and the car that would "evolve" (P22) according to user preferences.

The information in cars used to be provided through the instruments panel with analogue dials then carried to the central console with the screen technologies and today the information is again moving back around the instruments panel. Even with HUDs (head up displays) and WSDs (windshield displays) the information is located within the line of vision of the driver that is keeping drivers' eyes on the road instead of looking to the central screen occasionally. This creates a "flow of glances" (P28) a "visual choreography" (P15) within the car providing an "effortless interaction" (P7, P12, P15, P21, P22, P23, P28) to the driver as a part of flowing luxurious experience. However, the content of the screen (P21), a variety of information (P21) and visibility (P18) are also effective in terms of the experience. In addition to those the design of the screen elements and their relationship with the experiential settings (such as driving mode) can support the intended experience (P14). For example, the sport driving mode requires the information within the line of vision (P14) that can also be supported with a graphical representation of sportiness and mode-based content (e.g. information related with speed instead of fuel consumption (P14)).

Another important factor is the interactivity that is about all the input, output (information), the capabilities of the system and the relationship between them. The co-location of information and controls is a useful method for communicating the functions to the user to see the response of the system while interacting without looking at another location. For example, the use of the steering wheel for interacting with the central screen would require more attention and coordination in comparison to interacting with the instruments panel screen (P7, P15, P18). Also, as in the example of Audi TT air conditioning Figure 32 locating the information on to the control (depending on the size and location) might be quite useful in terms of accessibility of feedback (P13). However, in the case of touch screens where the information and the controls co-located this can also become challenging regarding the visibility which can be broken with fingerprints (P21).

Figure 32. Audi TT air conditioning controls

The capabilities of the system reflect on the experience as the response time, such as buttons light up just with a gentle touch (P2) or screen displaying actions on touchpad simultaneously (P5) as well as the ability to demist the windscreen immediately (P5). The responsiveness can keep the flow of the experience however, over-sensitivity of the controls can result in accidental interactions (P24) which can easily break that flow. Accidental interactions can be caused by “the size and the proximity of the controls” (P24) especially on the steering wheel.

The steering wheel is a relatively small area to include several controls which results in intricate, small sized buttons. These accidental interactions break the flow of the experience and direct driver to seek other means of interaction (e.g. central console controls) (P24). Another interactivity issue affecting the ease of use is the number of steps needed to achieve a task which is mainly about the systems' structure and planning. The layers of information structure, the precision of the physical controls as well as the audio command (P22, P11) could cause "excessive button clicks" (P16) and increase the number of steps. However, a precise and good planned HMI system such as the intuitiveness of the mobile phones (P24) reduces the number of steps providing an "effortless" (P20) flowing, luxurious experience. Lastly the information mainly depends on the visual representation however audio is also becoming a way of information presentation (P28) offering intuitive interaction with the system. The challenge and/or the opportunity is to design different modalities in relation to each other such as visual supported by audio or tactile feedback would create an easy to understand interaction and eliminate misunderstandings.

Ease of use is an important factor that is supporting luxury giving people the feeling of looked after and serviced by their car rather than challenged by it. The HMI systems are required to lessen the cognitive overload on drivers and have an assistive supportive role in the driving experience to offer luxuriousness. Another heading in the human factors cluster is the comfort which will be explained in detail in the following section.

5.6.2.2 Comfort

Oxford dictionary defines comfort as "a state of physical ease and freedom from pain or constraint" (Oxford Dictionary, 2019). Comfort (Figure 33) might seem to be easy to define however, because of the subjectivity and context-dependency of that phenomenon comfort can be defined as reducing the discomfort (Vink, Overbeeke, & Desmet, 2005). According to the study of de Looze, Kuijt-Evers and van Dieën (2003) the phrases are accepted within the literature; (i) comfort is defined subjectively, (ii) affected by context elements (physical, physiological and psychological) and (iii) comfort is a reaction to the environment. Our definition of comfort was mainly about the physical effort and ease and participants defined comfort as "materials and ergonomics bringing joy" (P18) and "ergonomically-friendly environment" (P14) "spending less energy" (P18).

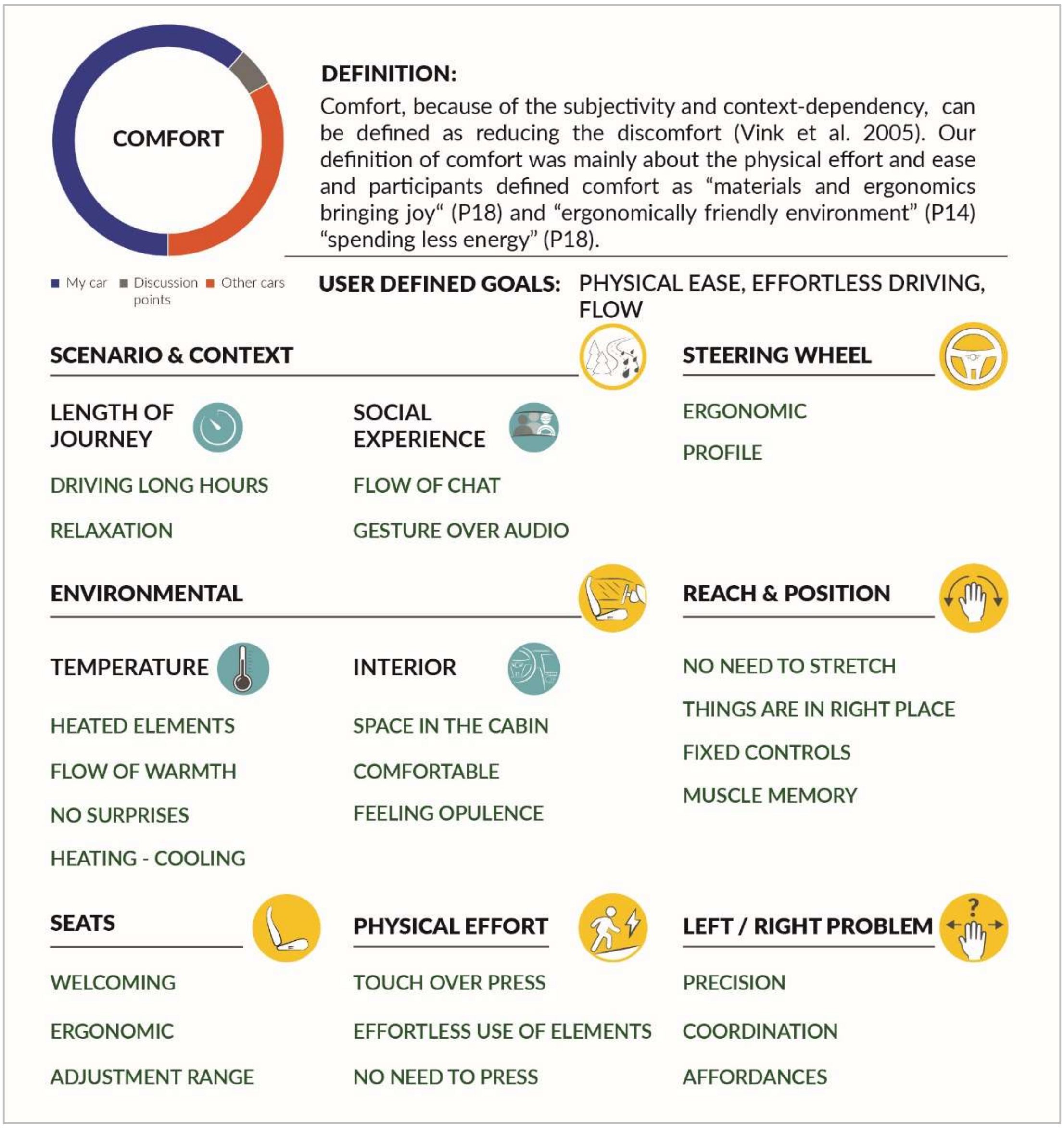

Figure 33. Comfort (graphical summary of comments)

Comfort is studied widely in car industry as it is quite effective in driving experience. The real value of comfort is appreciated during long journeys (P1, P6, P17, P18, P24), if you must drive for long distances and hours the design of the interior elements and ergonomics become crucial. Ergonomically designed, comfortable car interiors support driver and even after long hours you do not feel back pain (P18). That is also supporting the flowing driving experience as you do not need to stop and relax occasionally even in long journeys (P24). Another concern about the flow is social environment within the car that chatting with friends or family on rear seat or back seats. However, the audio feedback could become quite annoying by disrupting your conversation especially during use of navigation system (P9). Also, the audio command requiring you to talk could become disrupting from time to time which can be overcome by use of gestures for more comfortable interaction and driving experience (P9).

The environmental details especially temperature is quite effective in terms of comfort. Temperature setting was mainly about the air conditioning however for the last few years the heated seats and steering wheels became popular in car industry. The heated details especially within the cold winter days feel like “the car is cocooning you” (P18) offering you a delightful experience. This is can also be interpreted as a flow of touch (P1, P4, P7, P13, P17, P18) that the interaction is not interrupted with temperature changes. For example, sitting on to a heated seat and touching heated steering wheel in a cold day (P17, P18, P22, P26) or cooler interior and seating in a warm day (P4) can become “pleasant surprises” (P1) supporting the driving experience. In addition to the heating arrangements, comfortable interior can also be achieved through the spatial organisation of the elements (P14, P17). Especially the organisation and position of seats affects the way you perceive the car interior and can communicate the “opulence” (P16). For the interior organisation and comfort the two elements; (i) seating and (ii) steering wheels are important from drivers’ point of view. As the initial level of interaction with the car a “nice-shaped” (P28), “ergonomic” (P16), “welcoming” (P6) seating with a good adjustment range (P6) can provide luxury experience through comfort. Also, the steering wheel with its position, “profile design” (P18) and “ergonomic size and shape” (P6) is an important component of the driving experience.

Keeping everything within the reach of the driver is also another factor providing comfort and luxury. People set up a muscle memory (P4) within their car especially on the locations of the most interacted controls. That provides comfort through familiarity and feeling of security. The relationship between the driving position (P16) and controls are important for interior organisation. Over-reaching (P18) for controls can become annoying especially during driving, so the controls located within the drivers’ reach (P1, P7, P9, P11, P13, P23) provides a comfortable interaction environment without stretching to control (P11, P14, P18) things around. Fixed controls are perceived as more comfortable (P21) regarding muscle memory (P14) and drivers’ reach (P22). However, if they require stretching to achieve a task for the driver it does not feel “user-friendly” (P7) but challenging and “not luxury” (P18, P22). If the “things are in right place” (P22) considering the muscle memory and drivers reach range that could provide the luxurious driving experience without over-reaching for anything. Comfort can be related with high physical effort such as stretching however, the actions with low physical demand (pushing buttons, turning knobs etc.) could also communicate the level of service within a car. The effect of responsiveness of the controls without much physical effort might provide more comfortable experience supporting the luxuriousness. For example, the precision and responsiveness of touch-based controls servicing you just with gentle touch instead of pushing buttons (pressure and resistance) could communicate the luxuriousness (P14, P26). That is ability to manipulate interiors and interactions without physical effort (P26) supporting the feeling of being serviced by your car (P26).

Lastly especially UK-based drivers facing another challenge in terms of comfort because of the reason that most of the cars were designed considering the right-side drivers. The controls are in the right-hand side of the drivers in European cars and as most of the population is righthanded it is easier with their right hand to manipulate the controls precisely. However, in the UK, the driver is in the right side, so they need to interact with the central console with their left hand. This causes problems especially with the controls requiring precision and coordination such as writing on the touchpad (P5, P7, P24). Also controlling the HMI system becomes more compelling during driving to achieve tasks through use of their left hand (P2, P7, P24). The controls are being carried around the steering wheel and drivers immediate reach which could be a solution for the use of left/right hand for precision. Comfort is quite effective for the experience and feeling in car which was studied through ergonomics for years. Even though it is mainly ergonomics-related issues such as reach and positioning the small differences with heat arrangements and physical effort could produce the difference with the brands and bring luxurious experience. The next section will be discussing the effects of functions and features to the luxurious driving experience.

5.6.2.3 Interrelations within Human Factors Cluster

Ease of use and comfort are two close concepts that are built on each other. The interaction between them is summarised in Figure 34. In this analysis we have associated ease of use with cognitive load and comfort with physical ease and experience to differentiate them. However, the cognitive load is also related with physical ease as in the example of the location of controls could make them easier to use and also support the physical comfort in terms of reach and position. In addition to that the problem of left/right side located controls can easily become an issue of ease of use as well as comfort regarding again the physical effort, reach and position.

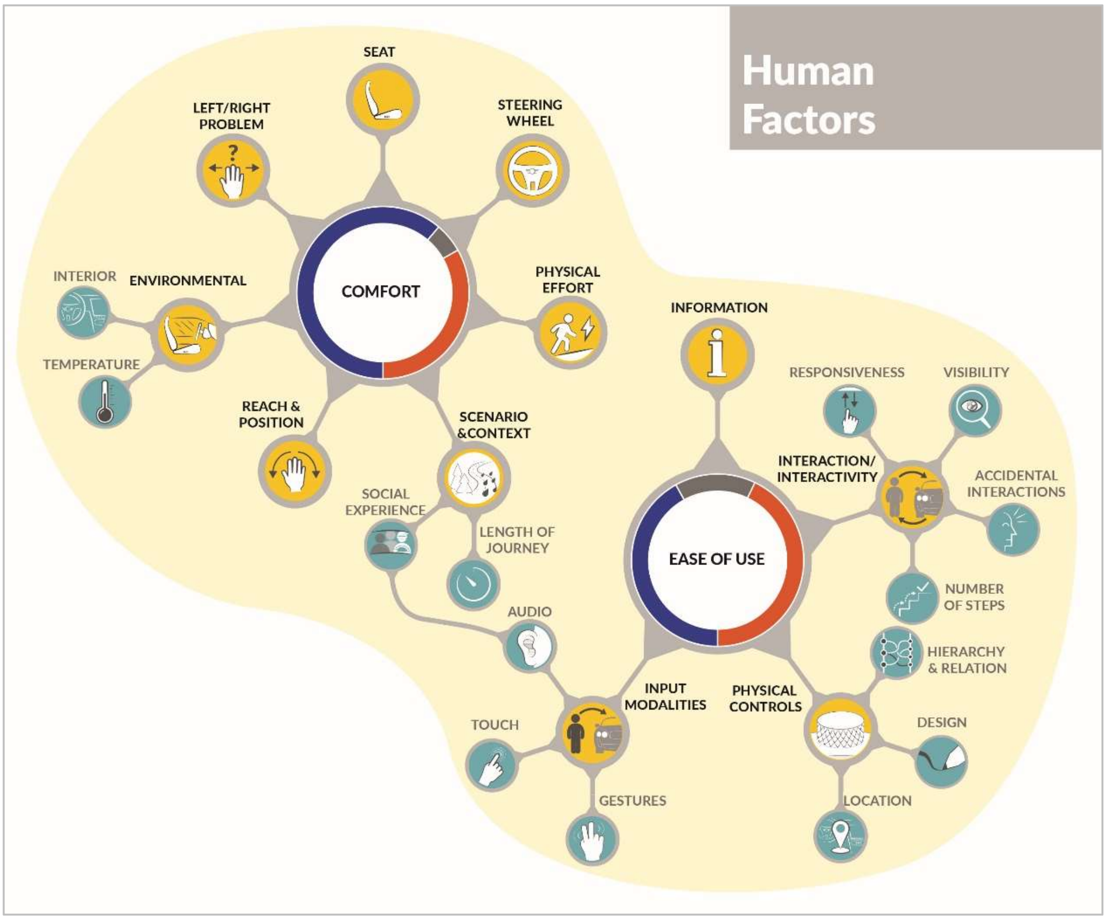

Figure 34. Interrelations within Human Factors Cluster

On the other hand, these two can conflict with each other in terms of experience as in the examples of use of different modalities for achieving a task. Such as use of audio over touch or physical controls can decrease the number of steps for interaction however, it can easily break the social environment in a car through making the driver talk to car instead of passengers. Another example is the location of the controls closer to the driver for reach and position (comfort) and ease of use can affect and reduce the space in the cabin and the feeling of opulence. Ease of use by itself cannot maintain the luxury as it can conflict with comfort or other clusters from time to time. As in the definitions of luxury UX (5.6.1 - Luxury UX) harmony and consistency within all clusters become crucial for maintaining luxurious experience.

5.6.3 'Functions and Features' Cluster

Participants' comments on the functions and features of their cars are classified under three headings: customisation, smartness and connectivity. As can be expected, most of the participant comments regarding the functions and features are about the use of technology and in-car interaction. The number of participants commenting on customisation (16) and smartness (16) are equal, followed by slightly fewer participants commenting on connectivity (10). The 'customisation' heading includes comments on: (i) options at production (concerns for manufacturers to consider during production) and options that participants would like to be customisable within their own experiences, (ii) physical controls and input, (iii) visual qualities (interior and screen), and (iv) information. Comments associated with 'smartness' created a three-step scenario starting with (i) recognition (user, context), moving to (ii) decisions and suggestions, and arriving at (iii) automation. Finally, comments on 'connectivity' revealed possibilities about (i) what to connect with a car, and (ii) how to connect in a driving context. The details of each heading are explained in the following section and summarised as graphics.

5.6.3.1 Customisation

Customisation (Figure 35) is used as an umbrella term including the concepts of personalisation and configurability. Even though there are nuances between these terms, they are closely related to and supportive of each other. Kratochvil and Carson (2005) explain the rise of customisation as a result of greater access to similar products and increased competition in the market. As customisation gives the user "the opportunity to partly determine the appearance or functionality of the product [they purchase]" (Mugge, Schoormans, & Schifferstein, 2009), it can have a strong association with exclusivity. In a luxury context, participants defined customisation as "making the car look how I wanted it to be" (P10) or "respecting to the users' opinion" (P17). Participants would like to have customisation options for "enhancing their driving experience" (P28) through "setting up a profile" (P20), with the car being organised and acting accordingly.

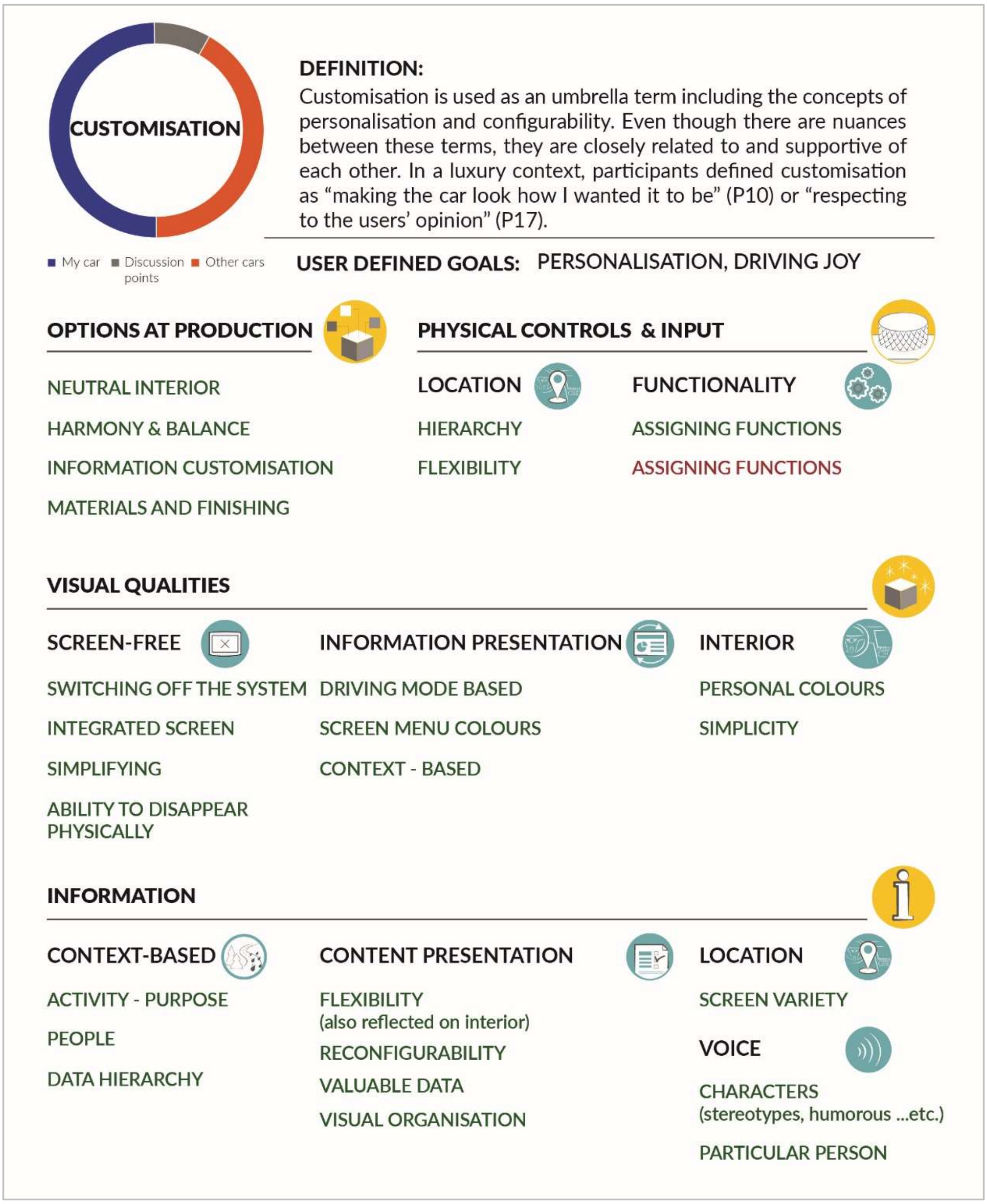

Figure 35. Customisation (graphical summary of comments)

The interviews revealed two dimensions of customisation: (i) options that are implemented at production, and (ii) options that are made during use. Options at production include clues for manufacturers to consider prior to delivering a car to customers, such as choices of neutral interior elements (P28). The design of interior elements should consider the fact that the screen elements are changing constantly (and partly customisable in some cars). It is therefore important to keep “balance and harmony” (P28) between the visual elements of a configurable screen and the wider interior design decisions. Another point mentioned by the participants was the “ways of having information” (P22) that can be chosen during production. An example is one driver who may want to hear information during driving, but another driver who may want to integrate vibration-based elements to their feedback experience, instead of audio information. Lastly, "surface finish choices" (P13) might be considered as elements of customisation during the purchase, as well as colour and stitching choices to raise the exclusivity for interior elements.

Options that people would like to customise post-purchase, as part of their driving experience, include (i) visual qualities, (ii) physical controls and input, and (iii) information. The participants mentioned the visual qualities of their car that they would like to customise during interaction and use. The main theme was again the dominating screen on the dashboard, as mirrored in comments on the 'form' heading in section 5.6.4 - 'Physical Embodiment' Cluster. Suggestions were made about how to better integrate such a large screen, for example through customisation of screen graphics in harmony with the visual qualities of the car interior (P28). The colour scheme and visual organisation of the screen enhance the driving experience (P28), particularly by reflecting different driving modes. However, from time to time participants also would like to be able to "switch off the system" (P23, P25, P28) to have a driving experience without information. One suggestion was to create a screen-free environment by physically hiding the screen (P25), but such a solution can create mechanical details that disrupt the visual flow of the interior. The main motivation to hide or reduce information is to simplify the interior of the car (P25), allowing the driver in certain contexts to focus on driving experience without disruptions. Such simplification is relevant not only for the main screen but also controls (P25).

Another issue that participants emphasized was the customisation of controls regarding physical location and mapped functions. Although there are standards and guidelines (such as ISO 15005 for dialog management principles, ISO 15008 for visual presentation of information and ISO 15006 for auditory presentation (Heinrich, 2012) for automotive HMI design, still one solution cannot be made to fully satisfy all drivers. People have got used to the flexibility of smartphones (P24) in terms of changing location of the controls, applications and orientation of screen. The flexibility of smartphones creates tailor-made interactions with a system and can be achieved through just a few clicks. Car interiors include several controls, some of which require urgent access for safety reasons. Nevertheless, there are still opportunities for flexibility. The controls related to infotainment functions may change from user to user, such as one user wanting to listen to music, but other choosing to use navigation for every journey. Therefore, the first user may prefer a sound source control to be located close within reach whereas the second user might prefer the same control mapped to navigation options. In such circumstances, users could define their own control organisation (P7, P24) for tailor-made experiences. However, it is important to consider the time and effort the user would spend to personalise the controls. The time and effort spent could turn the flexibility into a burden, detracting from a luxury experience (P10).

Discussion on flexibility also continued with reference to information provision in cars. Displays are becoming the dominating elements not only from a physical perspective in the car interior but also as a centralized hub of information provision. Screens typically include several layers of unrelated information, sometimes presented to the driver simultaneously, e.g. map, time, current song playing. However, participants pointed out that the hierarchy of their information needs changes with context (P4, P8, P12, P21), such as the purpose of the journey, presence of other people in the car, main information priority as navigation or entertainment. This needs-based hierarchy can be reflected in better organisation of information for a luxury experience. Another element of context is drivers themselves (user context) – who determine "the valuable part of information" (P21). This changes from one driver to another and requires a car HMI to offer flexibility in terms of information content (P21) and presentation (P10, P12, P20, P21, P28). Participants focused on the "reconfigurability" of HMI screens (P10, P12, P20) to personalise (P10, P21) the information presentation and achieve a preferred personal driving experience. One example of this "reconfigurability" is the LCD instrument cluster in the Audi TT (Figure 36) in which one can minimize the size of the speedometer and rev counter to reveal a larger map.

Figure 36. Reconfigurability of Audi TT LCD instrument cluster

Using screens additional to the main central screen provides flexibility to drivers in terms of the location of the information (P10, P28). In addition to visual information provision, voice assistance also offers opportunities for personalisation. Participants expressed that voice assistance is standardised across brands and does not appear to portray any specific 'human' character. Therefore, personalising the car's voice assistant character (P27) (e.g. stereotypical, humorous, caring), choosing from different voice options (P27), or even selecting a particular person's voice (e.g. famous people, family member) can create a bond between the user and the car.

5.6.3.2 Smartness

Smartness (Figure 37) is interpreted as the system's ability to gather data, make sense of it and act accordingly in a way that helps either the vehicle, its occupants or another target. Lee & Shin (2018) define a smart product as 'a product with human-like intelligence'. In luxury driving contexts, participants defined smartness as "car almost thinks on behalf of me" (P7, P16, P25, P26). By thinking on behalf of drivers, the car saves time (P20) and provides efficiency (P25) as well as physically easing or "taking pressure off the driver" (P4). However, how smart a luxury car should be is a matter for much debate. Participants considered that cars should "set up their own intuitiveness" (P20) but should not fully mimic human features. Instead of "being intrusive" (P20), the car should "know the right time to intervene" (P21) to create the experience of "being looked after by the car" (P12). Smartness can also be a way of creating a bond between the car and the driver, with the car "building a personality/character" (P27). Apart from all these positive effects of smartness on the user, cars should still offer an option to "turn off smartness to make driver feel fully in control of the car" (P4).

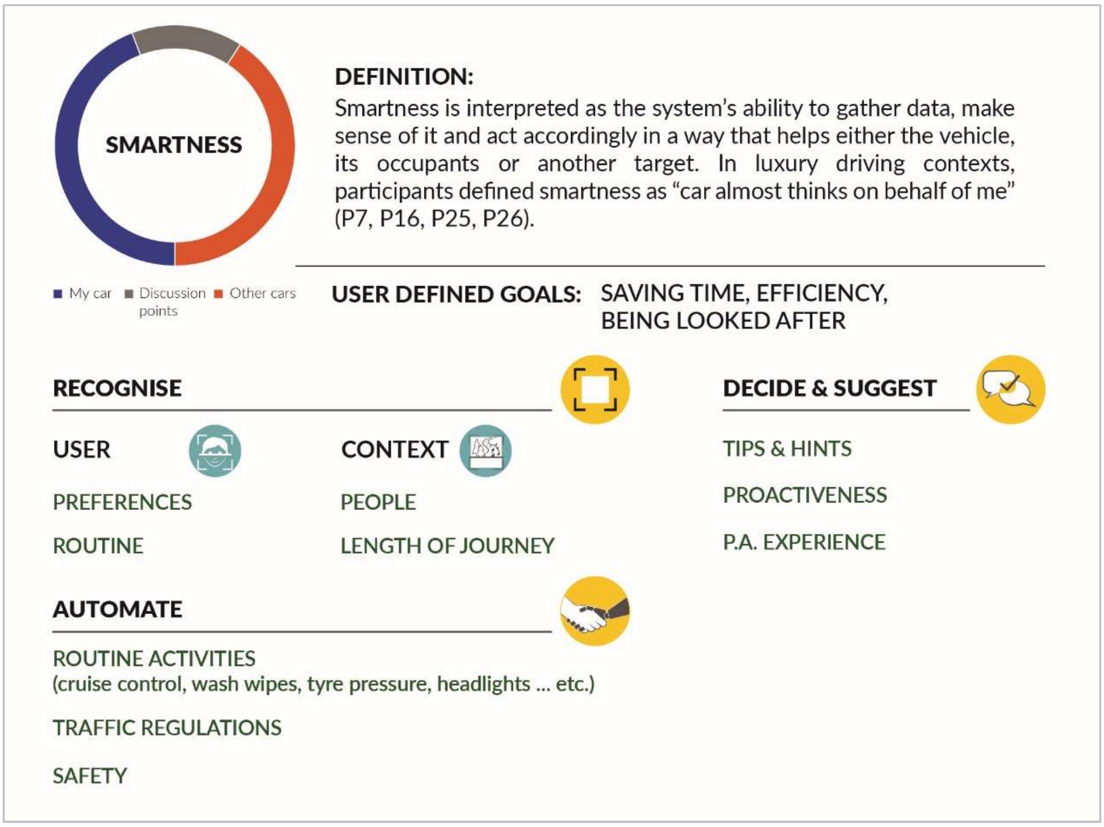

Figure 37. Smartness (graphical summary of comments)

Participants' comments on smartness revealed a step-by-step scenario involving the car learning, making decisions and eventually taking over or intervening. A smart car was considered by participants to initially "recognise and learn about its driver" (P16, P19) and "the driver's routine" (P22, P25). Smartness was stated as not preferable in every condition, for example the "length of journey" (P4) and "people in car" (P4) were factors that a smart car would need to recognise and take into account. For long journeys, smartness can be desirable as it takes physical pressure off the driver. In addition, the presence of other people in the car, such as children, can be distracting to the driver. In which case, the car can be smart so that it relieves the driver mentally. After the recognition step, participants' comments centred on the ability of a smart car to decide or suggest something, based on processing of the data it generated at the recognition step. In this regard, a smart car can act as a "personal assistant" (P14) that is "giving feedback, hints and tips about driving" and "building on what driver wants to do" (P20). However, it can also take over the decision-making process from the driver and become "proactive" (P20, P26) and "decide what is important for the driver at that time" (P21). This brings to the last step of the scenario, 'automate', in which participants focused especially on alleviating the driver during routine activities (e.g. keeping speed, dipping headlights) (P3, P4, P7, P17, P22, P26) that become boring after a while. In addition to these suggestions, compliance with traffic regulations and road conditions could be reflected in automated functions (P22). A practical example is linking current road speed limits to automated cruise control. Finally, it was mentioned that safety-related functions can easily be automated (P22) in order to prevent unwanted experiences for the drivers.

5.6.3.3 Connectivity

Connectivity (Figure 38) refers to the ability of one product to connect to another (often unrelated) product or system. Bécsi, Aradi & Gáspár (2015) summarise the elements in a connected driving scenario as (i) other cars, (ii) infrastructure (e.g. intelligent traffic signs), (iii) driving-based services (e.g. traffic management data, applications), (iv) the cloud (e.g. data storage or remote computing) and (v) smart devices (e.g. mobile telephones, watches). Participants defined connectivity as "interoperability of the system" (P8) and "integration of personal devices" (P3) to their car. The main motivation of participants was to create a "flowing experience" (P9) through the connectivity of devices. Participants expected such a web of devices to offer "choices of platforms" (e.g. Apple CarPlay, Android Auto) (P14), "borrow information from other devices" (e.g. music, real-time traffic information, preferences) (P1, P9, P25, P23), as well as “carry the information anywhere after driving” (P22). Connectivity also provides users the ability to use their phone functionality with “hands-free” (P1) option, creating a safe driving environment.

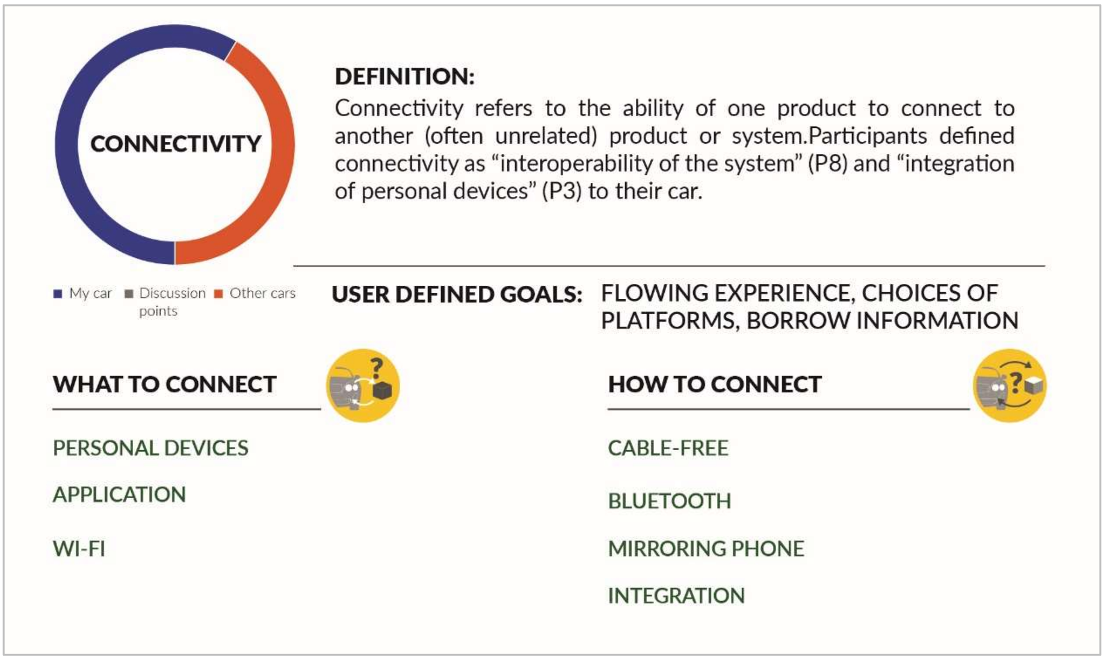

Figure 38. Connectivity (graphical summary of comments)

Participants comments highlighted two main concerns: (i) what to connect and (ii) how to connect. As expected, participants would like their cars to connect to their “personal devices” (P9, P12) and the main motivation for connecting is to access applications and related personal data (P9). People have got used to communicating through applications rather than text messages or even regular phone calls. Even the journey planning process has been carried to personal devices, providing a source of real-time, detailed information. Participants would like to have “cable-free” (P9, P24, P25) connection options (currently usually delivered via Bluetooth) and to have a connection “straightaway” (P25) so that the aforementioned “flowing experience” can be achieved. In order to keep the flow, they would like to “mirror the functionality of their personal devices to the cars’ system” (P22, P24) and control this functionality through car’s HMI (P9).

5.6.3.4 Interrelations within Functions and Features Cluster

The overlapping theme within the Functions and Features cluster headings is the use of technology. Smartness and connectivity are the results of technology, whilst ways of achieving the desired user experience with that technology come through customisation. Through the recognition of the user and the context (smartness), the process of customisation would become smoother. Furthermore, connectivity would support this recognition process by making use of data associated with the driver's other digital devices.

Location is an overlapping concern that appears twice in the customisation heading, concerning the physical controls and input, as well as information. Participants would like to be able to customise the location of controls and information to create their own dashboard organisation. Another overlapping factor that is similar between smartness and customisation is the context of driving. Participants ask for features that can be customised in line with a changing context. In this regard, smartness is a way of recognising the context factors and changing functions and features of the car accordingly. These interactions are summarised as a graphic in Figure 39.

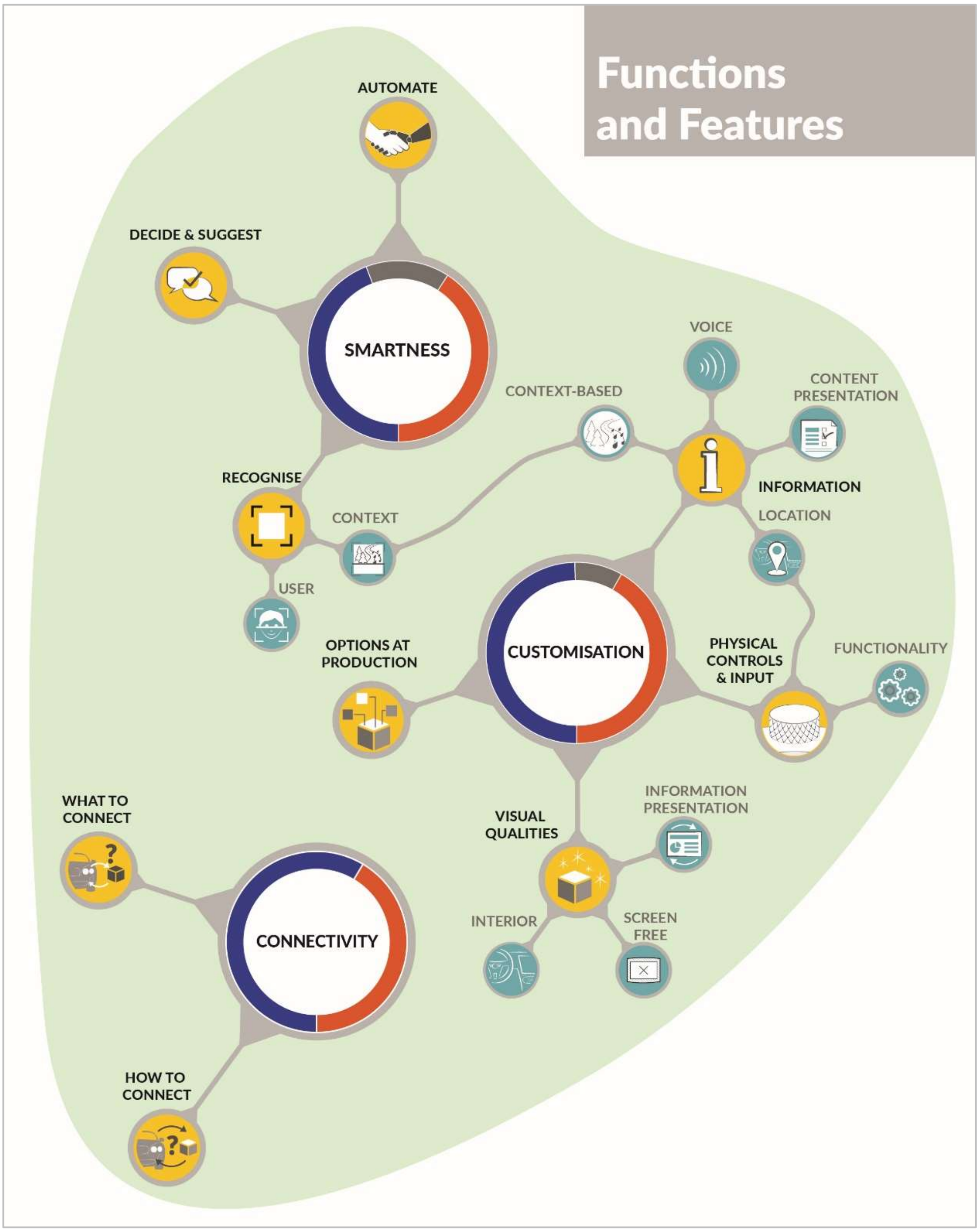

Figure 39. Interrelations within Functions and Features Cluster

5.6.4 'Physical Embodiment' Cluster

Participants' comments on the physical embodiment of their cars are classified and grouped under three headings: realisation, materials and form. The number of participants commenting on realisation (21) is higher than that of the materials (19) and form (12). Under the 'realisation' heading are comments about (i) manufacturing details (craftsmanship, graphics and labelling, mechanisms), and (ii) design details (lighting, sensory qualities, display specifications). The ‘materials’ heading gathers comments about (i) physical qualities (sensory modalities), (ii) meanings associated with materials (leather, metal and plastic), and (iii) the harmony, authenticity and brand associations of material choices. Under the ‘form’ heading are comments about holistic and component styling choices, as well as the challenge of integrating large screens within stylistic concepts. The details are explained in the following section with the graphical representations of each heading.

5.6.4.1 Realisation

Realisation (Figure 40) refers to the manufacturing and assembly details of an object. These are details that communicate a designers’ intentions to the user. Products are experienced as a whole, but on the other hand designers fine-tune every detail (Camere, Schifferstein, & Bordegoni, 2016) to create an intended experience for users. Realisation is what brings the intended experience to life (Hassenzahl, Lenz, Diefenbach, & Teck, 2015).

What determines luxury in terms of realisation are the “refined details” (P14) with all the “gaps and tolerances” properly mastered (P15), as well as incorporating challenging manufacturing and assembly techniques that are executed in a “wow” way (P6). However, squeaky, rudimentary, and easy to manufacture and assemble design details were considered by participants to feel cheaper and counter to luxury.

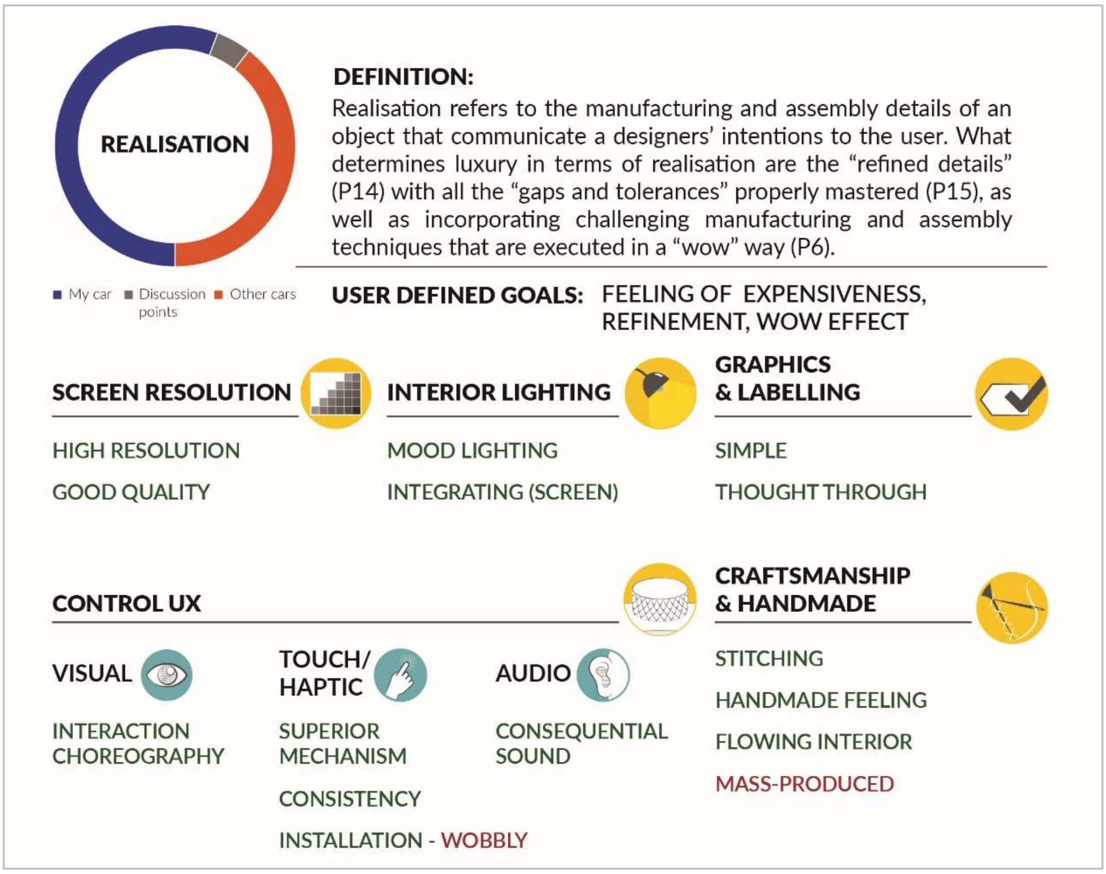

Figure 40. Realisation (graphical summary of comments)

Control UX is a major attribute of the automotive HMI that can be executed in a "wow" way, by maintaining the sensory consistency and 'feel' of the controls in the car. Even though basic switches were considered to be OK to feel "plasticky" (P19), "superiority" (P26) in the underlying control mechanisms is a way of communicating luxury. Superiority can be felt through haptics with smoothness, as well as audibly through consequential sound attributable to realization details. The installation of the controls should be sturdy not wobbly, and mechanisms should be confident not clunky (P2, P26, P28). A particularly insightful point about the controls is the "interaction choreography" (P15), which refers to the choreography of every movement that a control requires during instrumental interaction, such as a lid requiring a low-pressure activation touch and opening slowly and smoothly. This can communicate luxury more than a lid opening fast and sharply. However, a mechanism of a control that is working slowly can also cause confusion and annoyance when the main UX goal is responsiveness or urgency. So, the context is critical.

Craftsmanship and handmade details also give a feeling of luxury since they create the effect of exclusivity. The fact that it is "done by a person" (P16) for the user can be felt through the stitching details, especially on the steering wheel. Through craftsmanship, flowing interiors instead of angular mass-produced parts can be created (P6). Therefore, craftsmanship gives freedom to create unique interiors and more striking styling details in a car.

Realisation also refers to the physical quality of the HMI equipment integrated into cars. A principle item of equipment that is integrated is the central screen. However, with the latest trends, there are also other screens integrated into cars such as the instrument panel or head up display. The main attribute for a screen to be perceived as luxury was found to be the resolution. The resolution affects realisation of the screen-based interaction and the higher the resolution is, the greater the quality and clarity of graphics presented to the user (P1, P9, P10, P20).

Realisation of the intended experience is also affected by finishing processes, such as labelling and graphics on the controls. Those labelling details were found to become annoying and confusing in certain circumstances. White on black plastic is a preferred combination by most car producers due to the high contrast and readability during driving. But for some participants (P10, P25) it was felt to create a cheap feel, since it is too common and provides no exclusivity.

The final realisation factor of concern to participants was the use of interior lighting elements. Our vision depends on lighting conditions and it is changing constantly. The use of illumination can direct our attention to specific areas in the car interior, which in turn acts as a spotlight onto design and execution details.

5.6.4.2 Materials

Materials (Figure 41) are the main ingredients for physical embodiment of designed objects. As van Bezooyen (2014) states, they are the base of our experiences with objects and “designers paint with the materials”. As with painters’ experiences, designers communicate the forms they create through the properties of materials. Similarly, from a luxury perspective, materials are considered to be the “primary thing about luxury” (P16) since they are a prominent part of the initial experience with a product.

Materials have a crucial role in creating the perception of luxury through meanings associated with materials in time. Materials gain meanings through their sensory properties (universal meanings) and/or their frequent use in certain contexts (learned meanings) (Hekkert & Karana, 2014). For example: leather, wood and chrome are considered to be luxurious materials, where ‘luxury’ is an assigned meaning to those materials through time.

This perception is also reflected across different sectors of luxury including fashion, furniture etc.

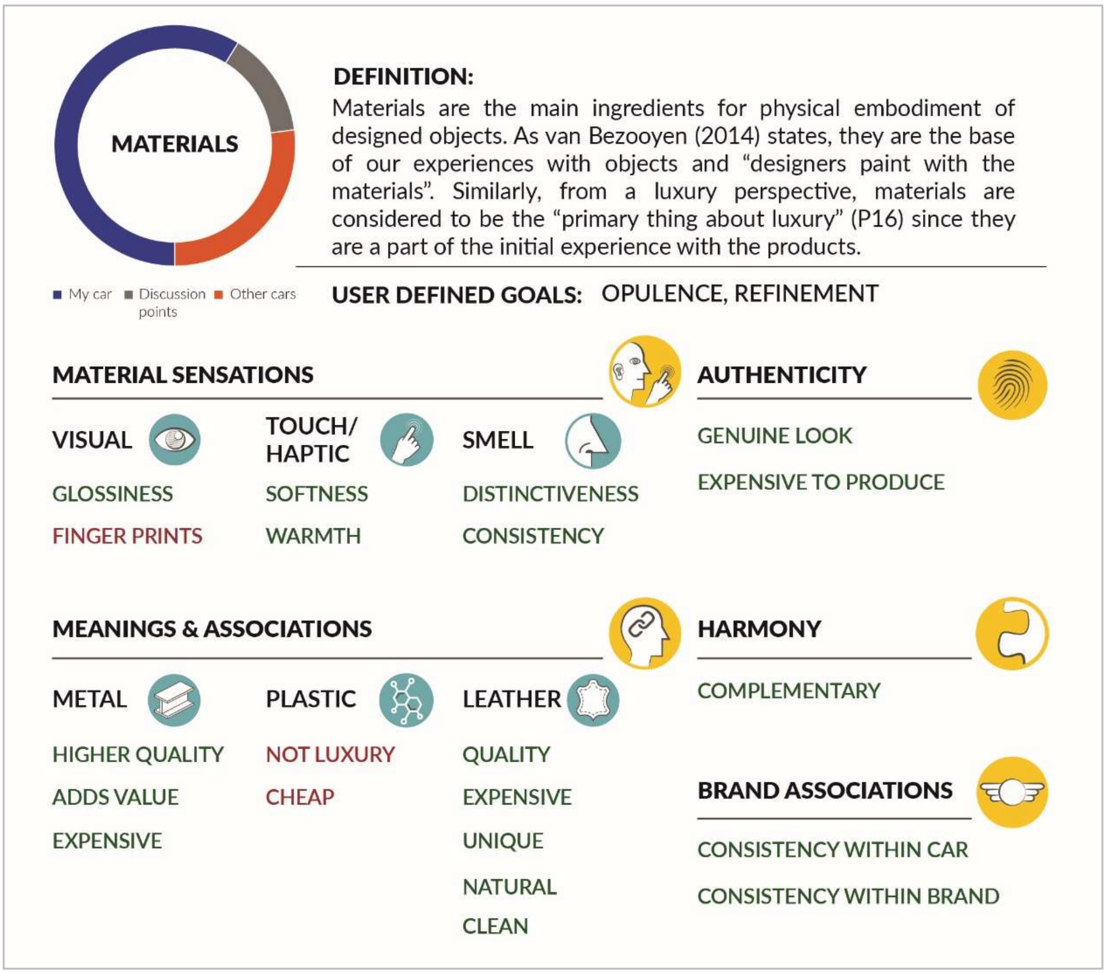

Figure 41. Materials (graphical summary of comments)

A common property of the aforementioned materials is that they are either natural, authentic materials (leather, wood) or have a purity in surface (chrome). They are associated with honest production and the use of those materials brings the sense of uniqueness and exclusiveness to people. If we focus on leather it is possible to see that the material is obtained from nature and each piece has a unique character. This makes leather expensive and, as a result, a relatively rare material used in production. That in turn corresponds with the feeling of becoming one of "the selected few" (Dubois, et al., 2001) consuming luxury. Metal, especially chrome, is also associated with luxury mostly because of its sensory qualities (cold, heavy, glossy-satin) and distinctive production details (e.g. knurling). Leather and chrome are commonly preferred over plastic in the context of luxury goods as "plastic feels cheap" (P10, P15, P19, P20) and is strongly associated with use in cheaper products.

Moreover, plastic can be replicated easily, meaning that it is neither unique nor exclusive to the user.

The meanings and associations of leather, wood and chrome are the main connections to creating a sense of luxury, but materials also gain those meanings through the quality of their sensorial properties. Participants' comments do not point-out a particular type or property of materials as inherently luxurious. Instead, the variety of comments about material properties reveals that luxury is created as a mixture of different elements "before and during interaction" with the materials. In terms of visual properties, high gloss materials are considered to be luxury (P8, P20). However, they create a fingerprint problem resulting in products looking dirty and thus compromising the luxury experience especially in touch screen usage scenarios by also preventing the visibility of information. The sense of touch and haptic feedback requires deeper analysis in terms of the location and purpose of the materials. For example, leather is perceived as luxury by participants if it is used on the steering wheel and seating as it is warm and soft. However, participants prefer to have cold and heavy-feeling metal on controls that they interact with across shorter periods, especially in situations where they need to locate the controls without looking. Moreover, even the use of plastic can become acceptable if it is used in the production of switches and controls (P19). However, still a combination of chrome and plastic is regarded as more acceptable than purely plastic switches and controls. Participants picked-up on the distinctive smell of leather, which is consistent through time and gives participants the same experience as on the first day of use.

Materials are one of the main components of luxury with their varied sensorial properties. If they are used in harmony with each other, they are able to create a visual and tactile flow. Materials also create opportunities for brands to build their identities through use of distinctive combinations in particular areas, alongside particular production techniques. Participants mentioned that their expectations for a luxury, exclusive experience should be consistent in a car brand and that materials usage across car models should also be consistent.

5.6.4.3 Form

Form (Figure 42) emerged as the third ingredient of physical embodiment, defined as the shape and structural characteristics of a product (Townsend, Montoya, & Calantone, 2011). According to Alexander (1973), a form ideally should reflect all the known facts relevant to its design. Thus, form is a way of communicating the usability and usefulness of a product.

Furthermore, the form can be used as a means to assign meaning to objects, to create a desired perception in users' minds. Luxury form within car interiors should be "challenging, more than functional, styled" (P6). The main goal of the form decisions for creating luxury is stimulation of excitement (P6) and the integration of different elements creating visual flow (P8, P20, P24, P28).

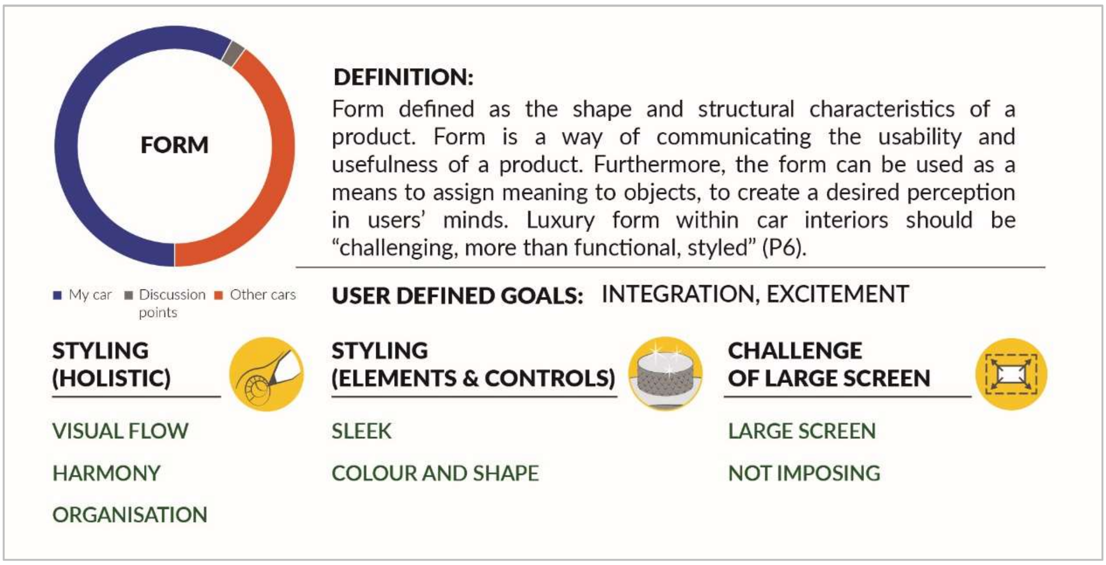

Figure 42. Form (graphical summary of comments)

For the styling of the car interior, the main point standing out from the interviews is the integration aiming to create a flowing interior. Since a car interior consists of several elements, the visual flow requires harmony (P6) between those elements. One of the challenges about visual flow is the constantly changing screen graphics and information. The design of those graphics (e.g. colour, shape) should also be considered when designing for interior flow. The other challenge is the ubiquity of a large flat panel screen. We are living at the age of information and inevitably the more information integrated into the car, the larger the screen becomes. Participants (P6, P8, P18, P20) emphasized on the larger screen supporting the sense of luxury. However, they are also uncomfortable about the fact that as the screen gets larger it starts to dominate the interior. In particular, an LCD flat screen display, with its material, changing graphics and colours, disrupts the visual flow created through flowing traditional wood dashboards.

Lastly, the design of the controls is also challenging as they can easily disrupt the flowing interior design. The colour and size of controls affect the perception of users, for example "big grey buttons" (P22) do not have associations of luxury. Controls perceived as luxury are defined as "sleek" (P13, P25) by the participants. This sleek look can be achieved by integration of controls to the touch screen or by the addition of visual elements such as chrome bezels.

5.6.4.4 Interrelations within Physical Embodiment Cluster

All the comments related to the physical embodiment cluster are classified under three headings, however, it is not possible to isolate these headings from each other. The comments of the participants within these headings share overlapping concerns and relations with each other. These overlapping points are summarised as a graphic in Figure 43. For example, the form of the controls is in relation with the realisation of those form decisions from the perspective of manufacturing and assembly details. Moreover, these form and realisation decisions are achieved through material choices. The sensory qualities of materials can create the desired effect on the user along with the form and realisation.

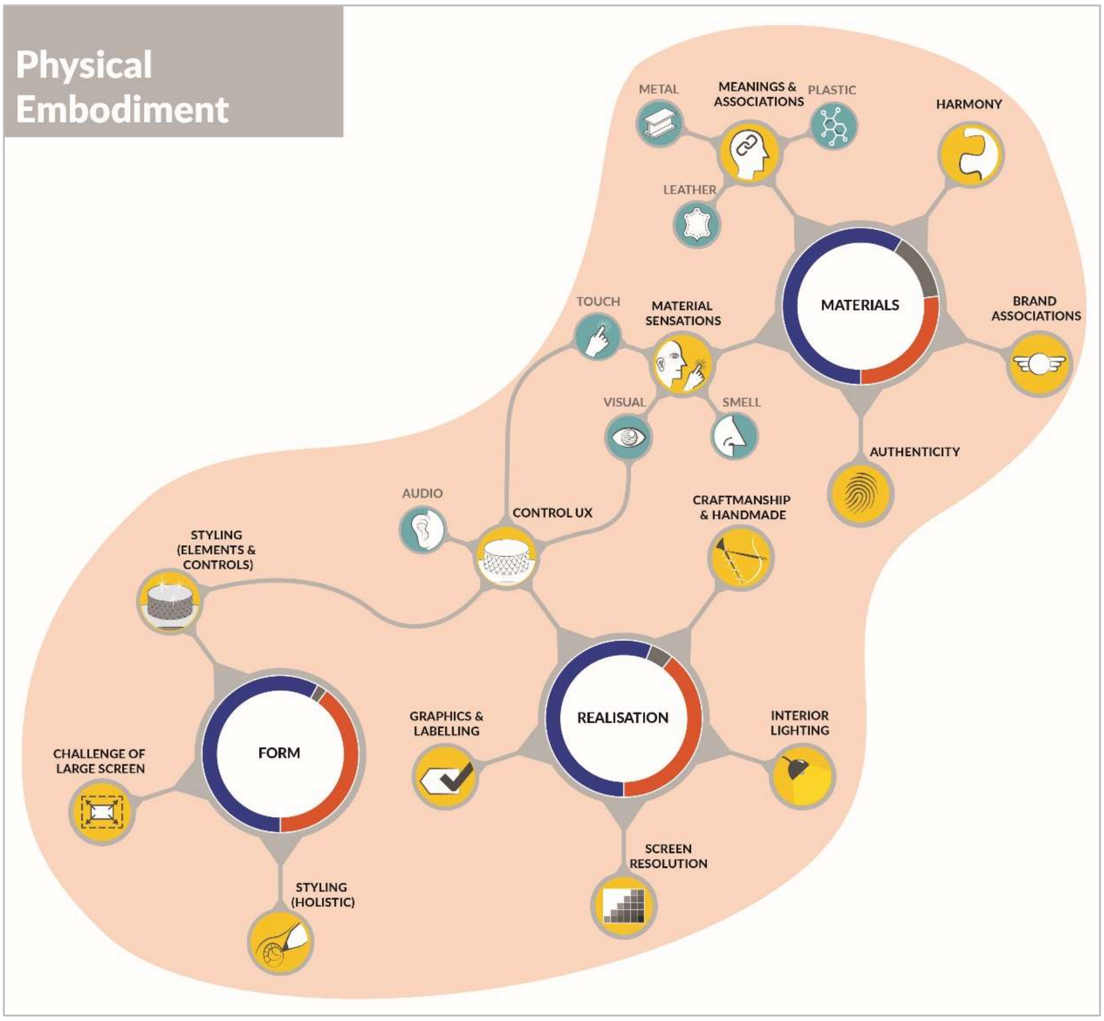

Figure 43. Interrelations within Physical Embodiment Cluster

5.6.5 Trends

As luxury UX, the trends heading also classified under discussion points. They are not discussed in the same cluster as they pose a variety of discussion points for luxurious design and they are not connected however supportive with each other. The comments about luxury UX discussed in the beginning of this section as an umbrella term that is covering most of the comments about other clusters. The discussions under the clusters were mainly about the design decisions communicating luxury in participants' cars and/or other cars that they have experienced. Finally, the trends (Figure 44**Hata! Başvuru kaynağı bulunamadı.**) heading is about the directions generally motivated by new technologies or inspired by other sectors that can direct luxury automotive design.

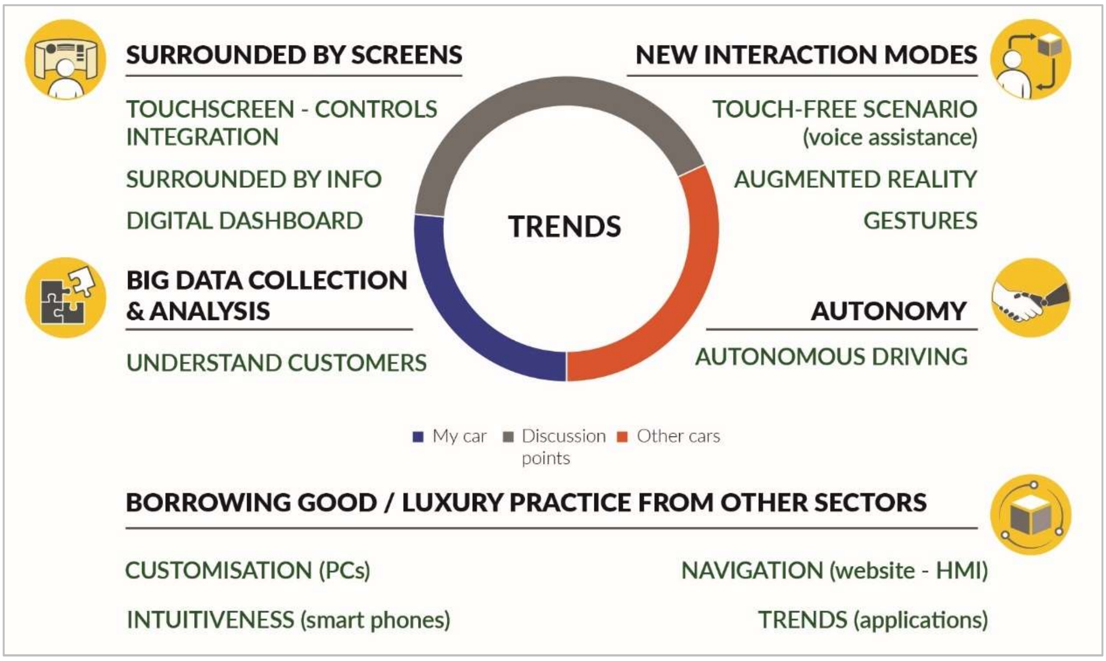

Figure 44. Trends that participants have mentioned

Participants tend to talk about their inspirations and wishes for the following cars and these are generally motivated by the technologies they have seen online and in events (e.g. trade fairs) or they have experienced in contexts other than driving. We are "surrounded by screens" (P9) providing us a variety of information throughout our daily lives. Mobile phones, tablets as well as screens located on several products offer information about the tasks and context to support our experience. This can easily be reflected on the car interiors such as digital dashboard applications (e.g. Mercedes E Class) (P12), instrument cluster displays (such as Audi TT) (P10, P12, P20). Moreover, the windshields could even become surfaces of information and interaction (P9) through use of see-through display technologies. Touch screens might be seen as popular for HMI systems (P8) today however, the interaction through touch or physical controls are still debated in relation to each other. There are several solutions ranging from multifunctional knobs to touch-only controls for interaction. Even though touch controls are found to be effortless (5.6.2 - 'Human Factors' Cluster) unfortunately they have accuracy problems compared to physical knobs. The solution offered in cars is touch screens integrated with physical controls especially knobs (P20) which can become a more effortless and accurate way of interaction.

Technology also brought new ways of interacting with the systems through gestural (P8), audio input which can discard the physical controls and offer flowing surfaces without intricate details. This may lead to a 'touch-free' (P1, P14) scenario controlling everything in the car without touching through gestures (P8) and audio (P20). Moreover, if the audio input can be executed as precise as our mobile assistants (e.g. Siri, Cortana) that could even become a unique selling point for car HMI (P20). Also, ways of information presentation are changing with the new visualisation technologies such as augmented reality (P9) providing ability to map information on the road through head up displays. This could make information more accessible and understandable offering user an effortless interaction.

Most of the solutions, as in the example of audio command, can be borrowed from other sectors. Computer (especially web sites) or mobile phone industries have been working on the information presentation and navigation for years. "Similar principles are applicable" (P21) for in car interaction regarding the screen-based information presentation such as the navigation principles of websites (P17) or the intuitiveness of mobile phones (P22). The novelty can be achieved through adaptation of these solutions to car HMI systems (P20) such as the customisation ability of mobile phones and computers (P17) can be reflected on the HMI displays. Another way of borrowing solutions from other sectors is to make collaborations and reflecting these solutions onto HMIs. The trending mobile applications can provide opportunities for integration to car HMI systems such as use of messenger applications (e.g. WhatsApp) instead of SMS (P9) and ability of the HMI system to adopt these applications could bring the novelty.

All these technological changes require time and research for them to be accepted by the users as some technologies are still debated. For example, automation is a trend that is directing many sectors for smart, fully automated environments such as the Amazon cargo robots working at the warehouse (Wingfield, 2017). However, autonomous cars (P17) are still debated in terms of cybersecurity and ethical issues (decision-making process of the cars and responsibility as well as security of the shared and/or stored information) (Linkov, Zámečník, Havlíčková, & Pa, 2019) . In addition to those concerns also the luxury automobile sector depends on the driving joy and experience which makes the autonomous driving (P15) the opposite of the experience they offer through their grand tour models. However, autonomy can be used for boring, routine activities as discussed in the section 5.6.3 - 'Functions and Features' Cluster offering the "butler (P15), concierge (P14), invisible waiter (P21)" experience to the driver. Most of the cars are already equipped with smart applications that have an ability to collect, store and share data, which may be used for another trend. Big data collection and analysis (P17) is the last trend mentioned that is collecting data about the users and the activities making use of it and reflecting these data on to the products. This can be used for automotive industry especially for understanding the routine of the users and offer automation through this data.

There are also several other trends and emerging, trending technologies that could be discussed within the luxury domain, however, this section was about the trends from the participants' point of view. In the following chapter (Chapter 7 – Provisions for Simulating Luxury Automotive HMI) the NEU (new, emerging and unusual) interaction technologies that could revolutionise car interiors will be discussed under the section 6.1 - New, Emerging and Unusual Interactive Technologies. All the clusters are in the luxury domain and related with luxury UX as well as the aforementioned goals can be achieved through trends and new technologies. The following section will be a discussion on the relations and direct connections between all clusters and headings.

5.7 Interim Conclusions and Recommendations

Luxury UX in automotive context can be achieved in many ways which are discussed in detail in the previous section. However, it is not possible to discuss these headings in isolation as they are all closely linked with each other in supportive or contradictory roles. The network between these clusters is summarised in Figure 45 showing the directly linked headings.

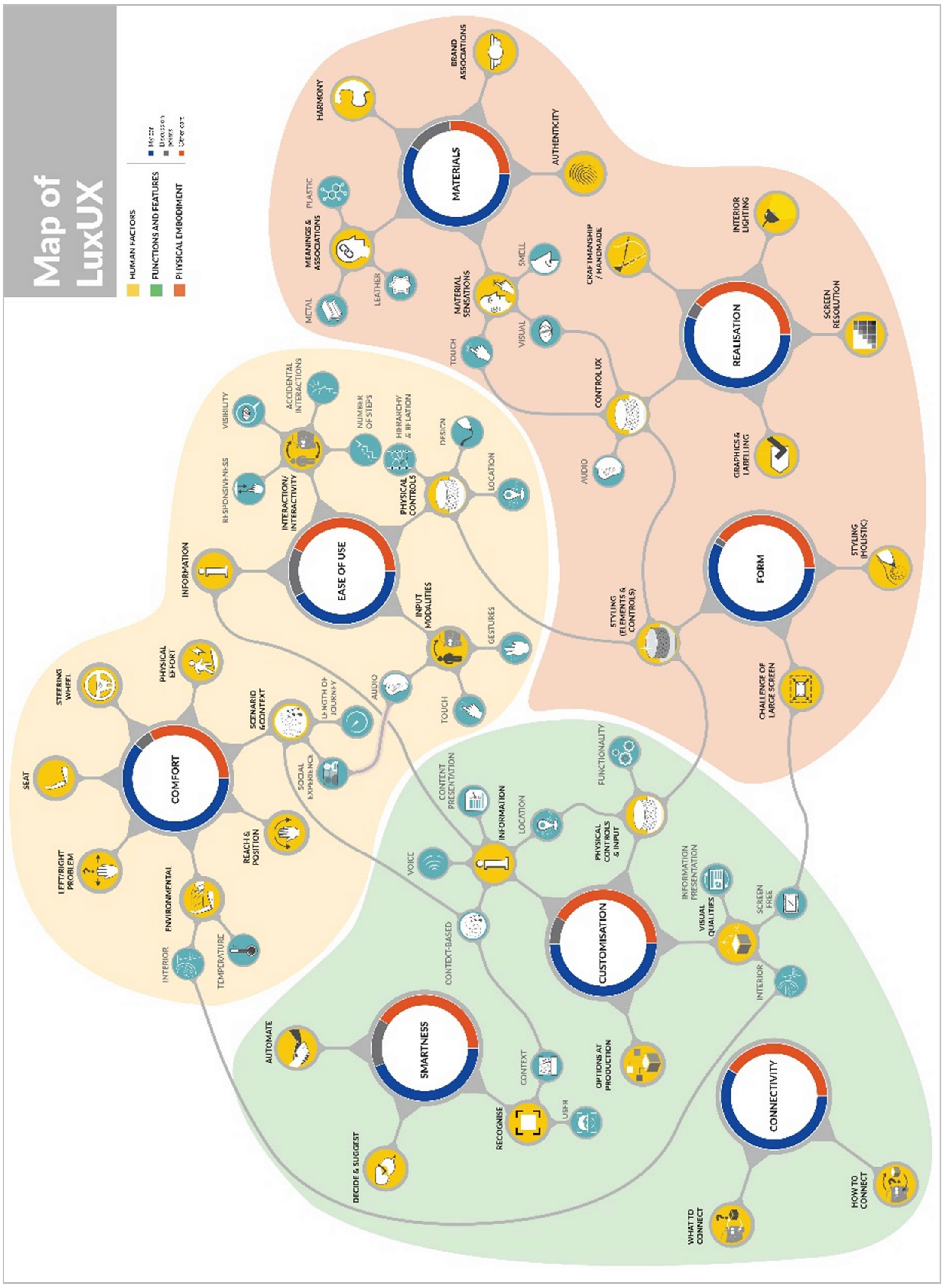

Figure 45. Map of LuxUX

The main theme that participants mentioned under different headings and clusters is the controls, the main input sources of the communication between the driver and the car. Controls can be classified as the initial step of interaction setting up the language for experience for this reason every design detail is important to deliver the message to the user. Controls can communicate luxury through a well-thought form that could symbolise the feeling of exclusivity that the form is produced for a selected few. The size, colour and details (graphics, textures etc.) are the clear indicators that the designers have profoundly analysed and understood the needs and demands of the users. Form cannot be produced regardless of materials as the well-designed details can be realised through use of certain materials as well as the finishing and production details. The precision and execution of the details such as knurling, with the feeling of the consistent texture and intricate details could communicate the expertise of the brand, the time & effort spent, and the investment made on the product. This precision can not only be understood by textures and visual quality but also through the consequential sound of the sturdy materials and superior quality mechanisms. Finally, the controls with their location, size and design details also affect the whole interior the flow and harmony could be designed and maintained through the form of the controls.

Controls are also important for human factors as the initial step of interaction their design could affect the interaction in positive or negative ways. The ease of use is not only about the design of the controls but also the relationship between them. The controls are not designed in isolation as they are a part of the whole structure that needs to work in collaboration with the user. The location of the controls should be in relation to this relationship and hierarchy between them such as the most used located closer to the driver. The location of the controls affects the hands-off time or the eyes off the road time regarding their visibility and accessibility. Therefore the organisation and design of controls generally based on safety concerns. However, drivers want to express themselves and have the feeling that their car is exclusive to them and for this reason controls also pose an opportunity for customisation and personalisation in terms of their locations, and the customisable functionality they offer. The use frequency of controls especially related with infotainment system such as music or navigation which are supportive but not crucial for driving experience is changing at an individual level. For this reason, the customisation of controls is also discussed in relation to the location as some participants asked for flexible, customisable controls because their use frequency of such controls is different from others. However, making everything customisable in a car could be interpreted as a workload on the user since it requires time and effort for users to assign functions to each control. Even though luxury is about ‘sense of control’ it is also about ‘being serviced by the car’ that is supporting or even thinking on behalf of the users through boring activities. The customisable details or the way user customises the HMI need to be defined regarding these facts as offering a certain amount of flexibility that can be achieved easily. For example, mobile applications in terms of their locations can be changed just with a forced touch which is easier compared to assigning functions on the controls.

Another dominant theme is the information provision as the second step of the interaction which is again closely linked with controls and the concepts of ease of use and customisation. The car interiors were designed considering the safety rules and regulations. However, today especially in luxury automotive sector designers need to provide more than the basic needs. As, with most products, cars are also equipped with a variety of information that is presented to drivers during their experience and some drivers need support whereas others would like to enhance their driving experience through extra information. The information provision especially regarding the visual presentation is determining where, when and how much time the driver will glance at which is essential for safety and driving experience. The location of the information and the relationship between the controls, shape the flow of glances and these are changing constantly especially regarding the context. In car activities, the purpose of the journey, the properties of the route and even the people in car are components of a driving experience and changing which information in what way the driver would like to have. For example, driving in sport mode would require a certain type of information, which is different from the eco-driving mode. Driving with kids or friends add social interaction into context and change the need for information and the way it is presented such as audio command or voice-based information provision could break the social interaction in cars. The preferences of the users can change in different contexts and settings which can be addressed through smartness. Cars are equipped with several sensors that could sense the weather conditions, number of passengers and even who is driving the car which can easily be reflected on the information provision in terms of locations, modality and content. Moreover, digitalisation of the content presentation adds flexibility in terms of content and locations making things customisable through offered choices.

Another challenge about the information provision is the dominance of the screen which is also challenging for interior design as well as comfort and customisation. The information provision in cars is mainly dependent on visual through screen/screens. However, with the new technologies (audio or tactile stimuli) and applications (i.e. navigation) which demand constant visual attention other modalities are becoming prominent and useful for information provision. This could change the car interiors and dashboards dominated by flat screens which are debated in luxury context as elements breaking the flowing 'wooden' dashboards. The technologies such as the see-through displays or projection could replace the dominant screens with an added value of ability to become invisible in certain conditions.

The invisibility of HMI is another demand of the drivers especially in low light conditions as driving at night or driving for joy in sporty mode in which whole attention is on the performance. This can offer the “invisible waiter” (P21) experience that is becoming invisible when not needed however, serving you perfect even without asking by monitoring you constantly.

All these elements are connected to each other however in this part the discussions were mainly on the direct connections that participants mentioned. The design process is a mixture of several components to consider for the unique blend of products communicating the exclusivity and luxuriousness to their consumers. Each designer and brand are creating their own formula mixing these ingredients for creating certain values considering their user/customer profile. In the following chapter the discussions will be on the researchers own process of designing for luxury through use of “the map of luxUX” and NEU technologies posing potentials for revolutionary car interiors. The chapter will be explaining the NEU technologies and concept designs through use of the map as well as criteria for setting up evaluation environments for luxury driving contexts regarding these facts and technologies.

CHAPTER 6

DESIGN DIRECTIONS AND SUGGESTIONS

The previous chapter revealed a map of luxury UX that consists of three clusters (i) human factors, (ii) functions and features and (iii) physical embodiment that are effective in structuring the luxury user experience. Those clusters and the headings are visualised as a network, a web of headings showing the main variables of maintaining luxury feeling in a driving context. The map indicates what to consider while designing for luxury as well as gaps and opportunities for luxury car HMI systems. The participant comments and the findings of the literature review show that luxury is mainly discussed and defined within the physical embodiment domain. However, the effect of interactive products and technologies that we face every day as a user, directs the luxury sector to define and design the ways of luxurious interaction.

The main ingredient for interaction is the technology that provides the opportunity to design responsive products, acting in collaboration with its users. Technology offers new, mostly intuitive and sometimes unusual ways of interacting with the products. This poses an opportunity of redefining and maybe even revolutionising the car HMI system as in the example of touch screens and mobile phones. We used to interact with our phones through number pads, however today the phones are produced without any physical control but the screen, with users interacting through technologies (face recognition, audio command). However, the car interiors are still based on physical controls due to the safety regulations and lack of research on each technology. Another technology integration problem in the automotive sector is the product development process which generally takes about 4-5 years, which is a quite long time compared to the pace of the technological developments.

This chapter is based on (i) the new, emerging and unusual (NEU) technologies posing opportunities for car HMI design, (ii) the reflection of the luxury UX map and new technologies on the design process (HMI design proposals). The first section is a technology audit on the NEU interactive technologies including examples of products, concepts, and applications. The second section explains the design process and the use of map of LuxUX (see Figure 45, p.134) and technology audit for designing luxurious driving experiences.

6.1 New, Emerging and Unusual Interactive Technologies

The digitalisation trend has changed the product development process that is now mainly directed by new technologies. All the products are getting digitalised which brings the opportunity of flexibility and smartness. Even though technologies are still discussed regarding the technology readiness of users and/or ‘smarty’ products patronising their users, they are still a source of inspiration for designers. The interaction is the communication between the user and the product, the design of which might lead to pleasant or frustrating experiences with objects. It is a cyclic process between the user and the product that consists of two steps as input (manipulation of the system by the user to communicate her/his intention) and output (the products’ ways of responding the users’ input). There are technologies that support either the input process or the output process. However, there are also technologies supporting both steps as touch screens. Touch screens are both input devices through touch sensitivity and output devices with the visual presentation ability.

In this study, the technologies are researched regarding all sensory modalities and classified according to their roles in interaction (Figure 46). The review included many ‘unusual’ technologies that are not used in commercial products such as gustatory (taste based) technologies. Those technologies are quite inspirational, however, they are in the research phase (regarding the complexity and relationship of taste with other modalities) and not expected to be used in commercial products for the near future. The initial list of technologies is prefiltered with the supervisor to reach a manageable number of technologies for both collaborating bodies would like to invest their time.

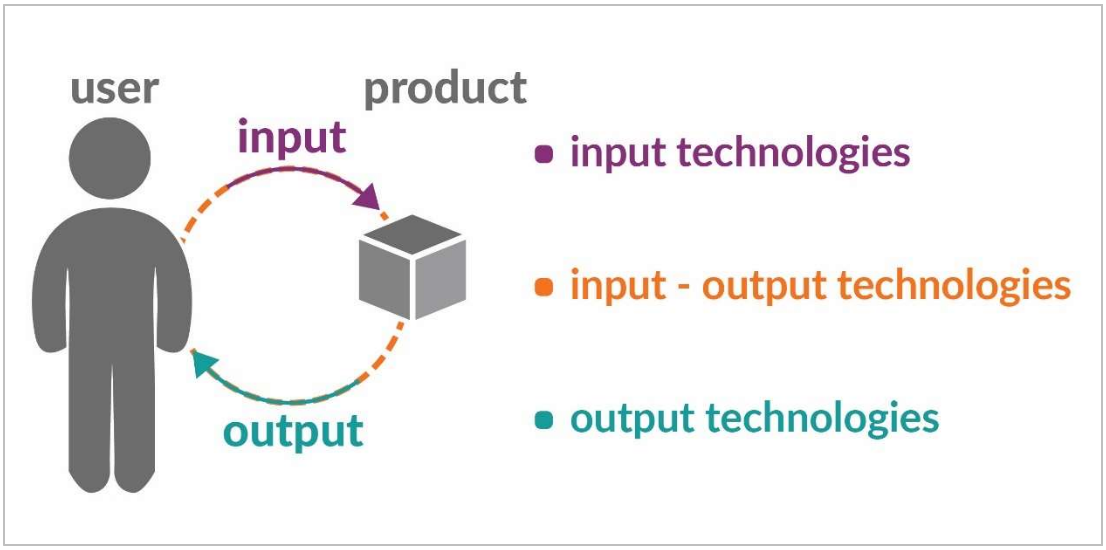

Figure 46. User product relationship

6.1.1 Input Technologies

As aforementioned input technologies are the ones that users communicate their intention to the system. This process can be achieved actively through manipulation of the physical controls, audio or touch input as well as passively through subtle input such as eye tracking which depends on the system actively assessing the changes (the location, centre, etc.) of the users' pupils. The filtered and chosen input technologies are; (i) eye tracking, (ii) acoustic (audio) fingerprinting, (iii) tactile touch displays, (iv) biometrics.

6.1.1.1 Eye Tracking

Eye tracking (Figure 47) is the process of measuring eye activity regarding the point of gaze (where a person is looking, what he/she is ignoring), the motion of the eye relative to the body, pupils' reactions to different stimuli and blink frequency. This data can be collected either by remote or head-mounted eye-trackers, generally consisting of two components: light source and a camera (What is eyetracking?, 2016).

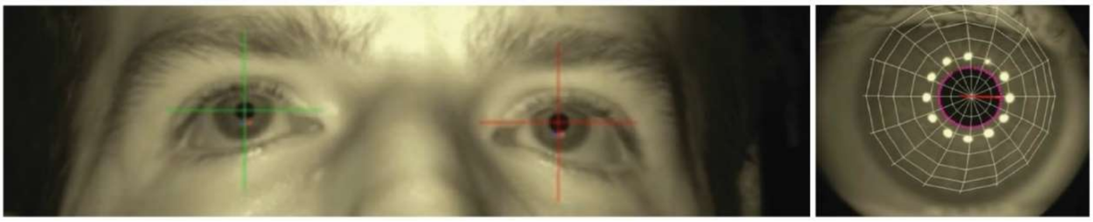

Figure 47. Eye tracking process (Vicomtech, 2014)

Eye trackers are commonly used as a part of evaluation environments especially for usability testing and marketing research, and gaze-based interaction is used for supporting the communication process for people with disabilities (i.e. cerebral palsy, ALS). Moreover, eye-tracking information (i.e. point of gaze, gaze duration) has the potential to be used as input for interaction as the in the study of Kim, Lee, & Dabbish (2015). The study interpreted this interaction in a shopping context collecting the point of gaze data to understand where the customer is looking and then projecting information on packages to augment packaging with animations and user reviews (Figure 48).

Figure 48. Shop-i gaze-based shopping (Kim et al. , 2015)

Eye tracking is a subtle and passive way of understanding the user intuitively. Giannopoulos, Kiefer, & Raubal (2015) reflected this interaction on a navigation application for pedestrians through 'the GazeNav'. The system basically tracks the gaze of the user to understand which way that she/he is looking, and the user's phone vibrates when the user is looking at the street that she/he supposed to follow. The system aims to dissolve the ambiguities of the navigation systems and offer a natural way of interaction which does not require learning and memorising.

Another example of gaze-based navigation is the study of Maurer, Trösterer, Gärtner, Wuchse, Baumgartner, Meschtscherjakov, Wilfinger & Tscheligi (2014) which offers the traditional 'passenger as the navigator' experience. Driving is a stressful activity and the secondary tasks could become distracting; this concept offers a collaborative environment in the car. The passenger is supposed to inform the driver verbally about the route and the passenger's gaze directs the driver to the exact point that he/she supposed to turn (Figure 49).

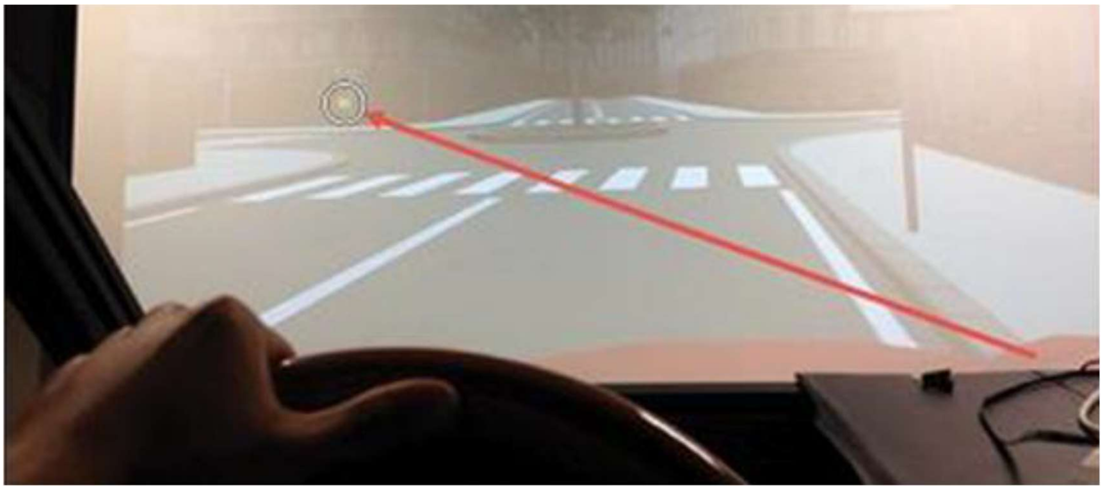

Figure 49. Shared Gaze driver passenger collaboration (Maurer, et al., 2014)

Gaze-based interaction also has the potential to be used in limited display areas as in the study of Akkil, Kangas, Rantala, Isokoski, Špakov & Raisamo (2015) focusing on smartwatches as they have a relatively small display area to be used with touch gestures. Gaze gestures such as left, right and up are used for browsing through the menu; using LEFT and RIGHT gesture for navigating, using UP gesture for selecting the particular item and rated positively by the users. Even though gaze-based interaction can be achieved with user-facing cameras, the need for an additional eye tracking device is the challenge for more accurate results. Khiat, Matsumoto & Ogasawara (2004) suggested a design concept for a gaze-based dictionary focusing on the reading patterns of non-native readers. The paper provides a possibility to track the eyes of the users while reading to find out the unfamiliar words according to the fixation time of their eyes on particular areas to offer translation to the user. Another example of the eye fixation duration is the study of Poitschke, Laquai, Stamboliev & Rigo (2011) focusing on gaze-based interaction with multiple screens in the driving environment. The study suggests a 'mouse-like' interaction with the combination of eye gaze for selection and buttons for confirmation and lets the driver keep their hands on the steering wheel while making menu selections.

Visual-based technologies are becoming more available over time and eye tracking devices can be used in the various evaluation environments. However, most of these technologies are in the phase of trials for defining new user-product interactions. As the driving context requires full attention for safety reasons it is crucial to lessen drivers' visual load, and this may be possible with the use of visual technologies to maintain the balance between viewing the traffic and the information systems.

6.1.1.2 Audio (acoustic) Fingerprinting

Audio (Acoustic) fingerprinting is a process based on a software algorithm taking a recorded piece of audio from any medium and creating a condensed digital summary of some of that particular recording's attributes. Using properties like frequency, intensity, and time, the fingerprinting software creates a virtual map of peaks and anchor points for those attributes (Gravell, 2016). These attributes can be used as input for interaction in various scenarios such as second screen applications. For example, smartphones and tablets are also becoming a part of our TV experience, second screen apps are making use of this habit and offering information (about the actors/actresses, soundtracks, etc.) about the show that people are watching. With audio fingerprinting, the applications recognise the TV or radio show that people are watching/listening to effortlessly and presenting them with related information or social media connections automatically.

Another example is SurroundSense, which is a mobile phone-based system designed for indoor localisation with accuracy. The notion of location is broad, ranging from physical coordinates (latitude/longitude) to logical labels (like Starbucks, McDonald's) (Azizyan, Constandache, & Choudhury, 2009). SurroundSense makes use of the ambient sound, light, and colour information in a place convey a photo-acoustic signature that can be sensed by the phone's camera and microphone. This information is used for precise localisation of the user such as the exact room that the user is located in a building.

It is also possible to use audio fingerprints as a base data for certain actions such as the University of Drexel ExCITe (Expressive and Creative Interaction Technologies) Centre researchers have done with the “HUBO” (humanoid robot) robots (Expressive Robotics, 2015). They have defined certain actions to certain audio pieces to make HUBO dance according to music. Moreover, they have manipulated HUBO robots to form a group performing a particular song, also with audio fingerprinting.

Audio information in a particular area or the song that is playing can easily become an input, a signal for a system to act accordingly. This could provide the user with a seamless experience that has the information or system acting in harmony with the contextual information without the user asking for it.

6.1.1.3 Tactile Touch Displays

Tactile touch displays are the shape-shifting displays created with the help of certain materials (generally microfluidics) to add tactile elements to touch screens which require constant visual attention for precision and accuracy. The microfluidics can be summoned on particular areas and rise up and mimic certain buttons on the screens such as a keyboard (Figure 50).

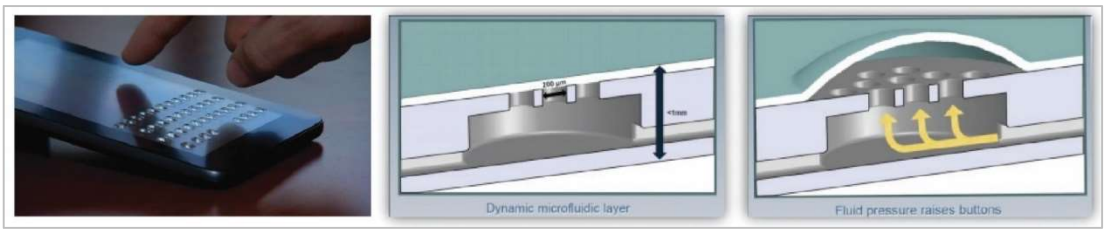

Figure 50. Tactus dynamic buttons (Tactus Technology, 2016)

Emergeables (Robinson, Coutrix, Pearson, Russo, Torquato, Nigay & Jones 2016) is a project focusing on adding tactual abilities to touch screens. An array of actuators has been used to create a surface that can deform or 'morph' to provide fully actuated, tangible controls. The aim of the project is to provide the flexibility of graphical touch screens, coupled with the affordance and tactile benefits offered by physical widgets. To illustrate, two prototypes with low and high resolution have been produced; (i) low-res prototype is produced with sensels (15mm each) moving independently (Figure 51, bottom) (ii) hi-res prototype has been produced with everyday buttons to illustrate the possibilities (Figure 51, top).

Figure 51. Emergeables prototypes (Robinson, et al., 2016)

The low-resolution prototype provides more smooth interaction because of its ability to move independently whereas the high-resolution prototype has the advantage of giving the user the exact feeling of buttons and sliders that are emerging on the screen.

Tactile touch displays can change the touch screen experience in the driving context. During the interviews, it is mentioned that even though it is effortless to interact with touch screens the demand for visual attention makes them difficult to use in the driving context. Tactile touch display technologies can overrule this demand by creating tactile feedback and redefine the touch screen experience within the driving context.

6.1.1.4 Biometrics

Biometrics is a broad term used to define certain characteristics of individuals that are measurable and distinctive. Examples to biometric identifiers include but are not limited to fingerprints, face recognition, palm veins, DNA, iris recognition, etc. These metrics are already used by security systems which require precise identifications. Also, some behavioural patterns such as typing rhythm, gait or voice recognition are classified as distinctive metrics of human characteristics. Biometric information can be used not only for security products but also in our daily lives for seamless interaction. An example is 'iris' (Figure 52) which is a personal camera that identifies the user with iris recognition and automatically loads his/her preferred settings. Also, the user can zoom in and out by just widening and narrowing her/his eyelids and take a photo by holding her/his gaze and then double blink.

Figure 52. Iris personal camera by Mimi Zou

Another use of biometrics information is the 'keyless grasp' bicycle lock (Tucker, 2015) that makes use of fingerprint for identification of the user. When the user grasps the lock, the system recognises the fingerprint (thumb) and unlocks automatically thus providing a seamless, effortless experience.

Biometrics information is generally used for identification, however, it can also be used for monitoring, especially for patients and disabled people. The 'dialog' is a wearable device that is claimed to predict possible seizures for epilepsy patients by identifying some biometrics information such as; heart rate, temperature, and hydration. Being connected to the user's smartphone the device keeps records of the seizures and biometric information of the user, and also notifies the caregiver in case of a seizure occurs.

Biometrics can be used for identifying or monitoring data which can be about health, emotions, etc. that can also support the automation of some activities in the driving context. An example is the comfort and temperature arrangements getting ready before the driver enters the car. This can provide the seamless 'the invisible waiter' or 'the butler' experience to the user, supporting the feeling of luxury.

6.1.1.5 Smell Capturing

The sense of smell is overlooked in most commercial products. The olfactory system is complicated and complex with its chemical and subjective properties. The relationship between smell and car interiors has been discussed within the new car context (Jordan, 2000) as a 'technical smell' makes people feel pleasure when they sit on the driver's seat. The smell can become an input medium through capturing, which is possible, with headspace technology. The technology involves an airtight hollow dome surrounding the object (whose smell will be captured) and with the help of a vacuum, odour is captured by various techniques such as solvents, absorbent materials.

'Madeleine' (Figure 53) by Amy Radcliffe (Stinson, 2013) is different from conventional cameras in that it captures the smell information of objects instead of an image. When scented objects are covered with the glass dome, the odour travels through a tube and is absorbed into a trap made of polymer resin. The rest of the process requires this 'trap' to be analysed and the smell to be produced synthetically by scientists and send back to the user.

Figure 53. Madeleine scent-ography

The sense of smell as a means of interaction needs further research due to its complexity and subtlety. It is not an instant way of conveying or capturing information, but it has a certain link with memories and emotions. Furthermore, cars and journeys are areas where people experience emotions and capture memories; that is why a smell can be an important interaction medium for in-car applications.

6.1.2 Input – Output Technologies

As mentioned at the commencement of this chapter, input-output technologies are the ones that users give information to the system about what they intend to do with the system and also receive feedback through. These technologies are achieving both steps through manipulation of the system actively (i.e. flexible displays) or passively (i.e. intelligent user interfaces) and systems act according to these manipulations and give feedback to the user. The filtered and chosen input-output technologies are; (i) flexible displays, (ii) deformable displays, (iii) shape-changing interfaces and (iv) intelligent user interfaces.

6.1.2.1 Flexible Displays

Flexible displays are the displays created with e-paper and OLED (organic light-emitting diode) technologies which enable the display to be flexible and bend. These displays consist of films and OLEDs instead of glass which enables them to be durable against falling but also makes the screen vulnerable after a certain number of bends. The fully flexible displays also created possibilities for new interactions as illustrated in the project ReFlex (Strohmeier, Burstyn, Carrascal, Levesque & Vertegaal, 2016) which is a concept smartphone. With the flexible display technology, the ReFlex offers an experience that is close to the very basic habit of turning the pages of a paper book. The experience is illustrated in Figure 54 where the user is bending the screen in a particular style to flip the pages of a book or to play a game.

Figure 54. ReFlex bending to flip pages (left) and to play a game (right) (Human Media Lab, 2016)

In addition to flexibility, these displays can also be folded as in the concept of the Samsung Smartphone (Smartphone2016, 2016). Foldable displays give opportunities such as making the display get smaller or even disappear from view when it is not in use, dividing the display into a particular number of pieces and even using the display as a stand for itself. Lenovo's flexible phone (Figure 55) and tablet concepts also offer different usage scenarios. Users can achieve various tasks through the use of smartphones requiring larger or smaller screen area or different holding options. Use of flexibility provides the ability to wrap the phone around the user's wrist and turn the smartphone into a smartwatch with a smaller screen area.

Figure 55. Lenovo foldable concept (Velazco, 2016)

Foldable displays pose opportunities for car interior for 'invisible HMI systems' that can be folded away when not in use or for easy to carry car accessories that can be used for achieving tasks away from the car.

6.1.2.2 Shape Changing Interfaces

Shape changing interfaces have the ability to change their shapes physically. This can be made possible by material properties (changing shape with heat, electricity, mechanical or electrical properties that are computationally controllable, etc.), designed structure, or mechanics.

PneUI (pneumatically actuated soft composite user interface) (Yao, Niiyama, Ou, Follmer, Della Silva & Ishii, 2013) is a study that makes use of composite material structured in layers with different mechanical or electrical properties that are computationally controllable through pneumatics. The study was focused on four applications; height changing buildings (Figure 56, left), a morphing mobile (Figure 56, middle), a transformable tablet case (Figure 56, bottom right) and a shape-shifting lamp (Figure 56, top right).

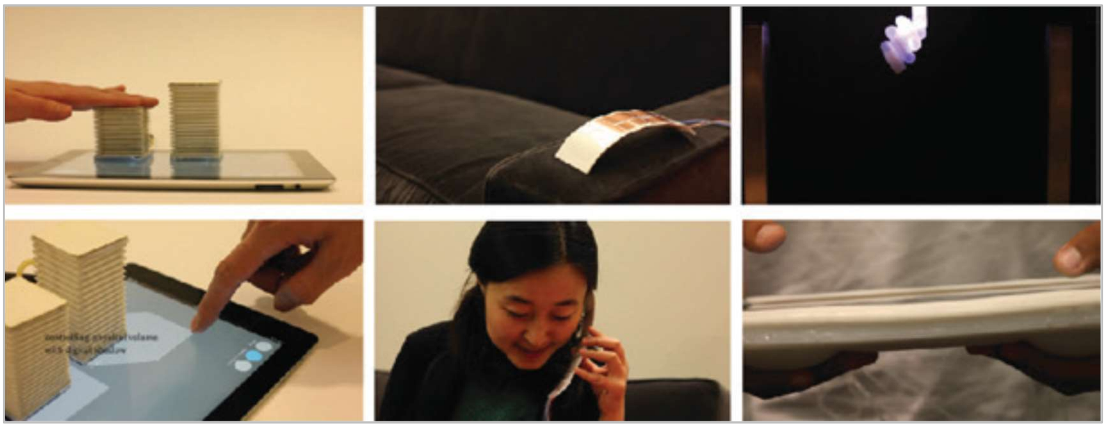

Figure 56. PneUI applications (Yao, et al., 2013)

Shape changing interfaces offer a tangible experience with the objects, which might be reflected in car interiors as changeable dashboard elements according to contextual elements.

6.1.2.3 Intelligent User Interfaces

Intelligent user interfaces are interfaces using several techniques (i.e. user modelling) to perform reasoning and learning and to adapt to users' needs and wants. These systems get input from the user with an audio command, facial recognition, etc., and keep user-based information gained through interaction. The system keeps updating and adapting itself according to this information and to users with machine learning and context awareness and finally gives feedback to the user (with i.e. speech output, tactile feedback).

An example of intelligent user interfaces is Nest (Nest Learning Thermostat, 2016), a thermostat with the ability to learn user preferences through time. It learns the habits, daily routine and preferences of the users and adjusts itself accordingly. The thermostat turns itself down when the user is away or heats up the house according to the users' routine which can also be controlled through smartphone applications even away from home.

Intelligent user interfaces offer several opportunities for several products. The challenge is to provide the appropriate level of service to the user without interruptions. Intelligence can become a way of providing product and brand attachment as well as to keep the surprise and delight effect throughout years by evolving with its user.

6.1.2.4 Deformable Displays

Deformable displays are produced with specific methods or flexible materials that enable users to physically push, pull, bend or flex the display. It is also possible that these actions are performed by the display itself to better represent the content. Screens offer a two-dimensional environment to the user, however, from time to time the information presented needs to be viewed in a three-dimensional manner. Deformable displays offer this experience and it is exemplified by a medical process of viewing brain scan information. Brain scan information consists of the 3D scan of the brain shown as sections and traditionally this information can be seen as images side by side.

Use of deformable screens as in the project GHOST (Generic, Highly-Organic, Shape-Changing Interfaces) (Jansen, Dragicevic, Isenberg, Alexander, Karnik, Kildal, Subramanian & Hornbæk, 2015) offers another way of interaction such as pushing in the screen to see deeper layers of this 3D information (Figure 57). This process defines a novel way of interaction and information provision by pushing and pulling the screen instead of tapping, touching, swiping, etc.

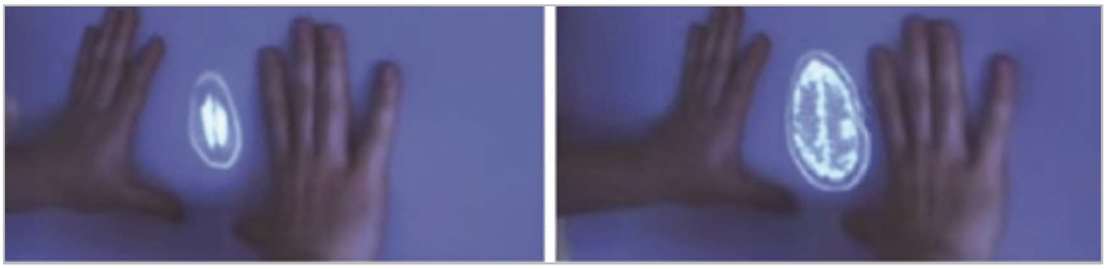

Figure 57. Interaction with deformable displays

Silke Hilsing's (2009) project 'impress' (Figure 58) defines a three-dimensional experience with touch screens by actually manipulating the screen itself. The screen is built with an additional layer of soft and flexible foam letting users manipulate the information by pressing and squeezing.

Figure 58. Impress project interaction

Deformable displays provide opportunities for tangible interactions with the system turning flexible materials to screens and changing the visuals accordingly. This might reflect on the interiors as projections on seating as well as interactions through soft material areas (i.e. seating, steering wheel).

6.1.3 Output Technologies

Output technologies are the second step of interaction, where the system provides feedback or acts according to the user's manipulations of the system elements. This feedback can be given through all the senses to the user ranging from visual (such as screens, lights, colour change) to certain smells. The filtered output technologies are (i) texture and softness changing interfaces, (ii) see-through displays, (iii) artificial textures, (iv) spatial sound, (v) focused smell.

6.1.3.1 Texture and Softness Changing Interfaces

It is possible to manipulate the passive properties such as texture and firmness of particular materials because of their characteristics. Such changes in firmness and texture generally happen gradually and can be used to convey information about gradual changes.

Bau, Petrevski & Mackay 's (2009) BubbleWrap project provides active feedback through vibration and additionally controls the shape, firmness, and texture of a particular textile. The stretchable fabric is manipulated through magnets and coils resulting in vibration and changes in firmness and shape. Changes in firmness and shape can be used to communicate gradual changes as in the example of battery life of a mobile device whereas different vibration patterns can be assigned to different functions such as an incoming call or message. The change in texture and firmness can communicate several things in a car ranging from navigation to speed to the driver through the seating or even the steering wheel. The subtlety of this interaction can create flowing experiences that are warning or informing the driver on non-urgent issues.

6.1.3.2 See-through Displays

See-through displays present dynamic and interactive information to the user on a transparent surface. The advantage of the transparent surface is to make it possible for users to see through the display while watching the content on the screen. This brings the ability to overlap certain information (photographs, dynamic content, text, etc.) on other physical objects or views.

The use of see-through displays can create a range of usage scenarios. One of these scenarios is built by LG for a smart fridge (Figure 59) which has a door made from a half transparent screen. This screen can be used as a regular touch screen and is equipped with various apps. In addition to this, it is possible to see what is stored inside the fridge.

Figure 59. LG Smart fridge (Mobilegeeks.de, 2016)

See-through displays are already in use in the automotive sector as head-up displays that are embedded in cars or integrated as additional screens. Use of head-up displays in an automotive context is mainly utilitarian, however, they pose additional opportunities regarding the experiential attributes. Integration of smart applications adds to these screens the ability to map information on exact elements (buildings, trees even animals moving around) which can enhance the driving experience through added information.

6.1.3.3 Artificial Textures

Artificial textures augment the experience with touch screens which are generally just flat surfaces or with any object that requires additional tactile elements. These textures can be created with electrostatic vibrations (weak electrical signals) with these signals varying in shape, amplitude, and frequency to provide a wide range of tactile sensations.

TeslaTouch (Bau, Poupyrev, Israr, & Harrison, 2010) is one of these studies making use of artificial textures through the use of electro vibration to create a broad range of tactile sensations by controlling electrostatic friction between an instrumented touch surface and the user's fingers. Tesla Touch (Figure 60) can create only one signal on the whole surface and only a moving finger will feel that signal, so it is necessary to design a sequence of actions to feel different tactile sensations.

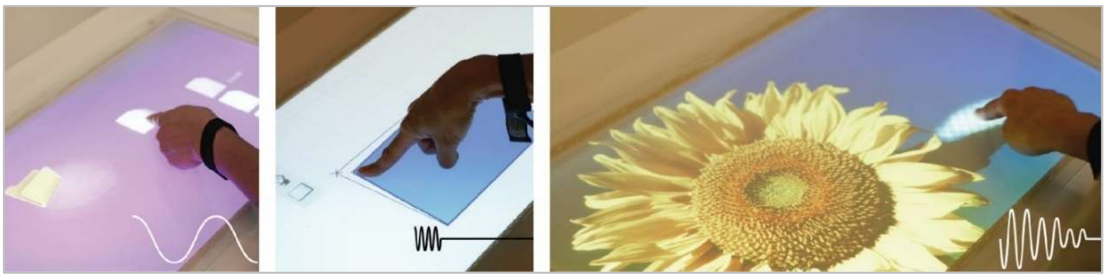

Figure 60. TeslaTouch Technology (Tesla Touch Project, 2010)

Another study directed to the creation of artificial textures is REVEL which also offers the ability to augment not only touch screens but also any object. Bau, Poupyrev, Israr & Harrison (2012) explain the project REVEL as injecting weak electrical signals varying in shape, amplitude, and frequency to provide a wide range of tactile sensations. This device can be embedded in several objects such as a chair, shoe, and painting or on potential surfaces with projections to augment the experiences with these objects.

Artificial textures might be used in several areas ranging from museums, to mimic textures of vulnerable objects/paintings, to furniture, to offer different textures in one product. That equipment can also be embedded in several areas in a car to present information to the driver through subtle ways or to mimic physical controls in certain areas for ease of use.

6.1.3.4 Spatial Sound

Experiencing spatial sounds is possible with a binaural recording that is placing the microphones on a dummy head at the locations of the ears. The recordings then can be played as a simulation of the real environment augmenting the virtual world. These technologies highly used in the gaming industry such as the Ossic X (Prindle, 2016) headphone is a project in progress.

Figure 61. Ossic X experience (Prindle, 2016)

Spatial sound can be experienced with ordinary headphones, but the problem is sound also moves with the user. In real life the sound is stable or moving in accordance with its source. To have such a realistic experience Ossic X (Figure 61) has an integrated calibration system to track the location of the head to keep sound stable even though the user moves.

6.1.3.5 Focused Smell

Smell can also be considered as a subtle way of interaction, but it is imprecise regarding the fact that it tends to dissolve in an area which cannot be controlled. The study of Yanagida, Kawato, Noma, Tomono & Tetsutani (2004) offers ways to focus smell in a particular area or on a person's nose to make it personalised. Yanagida et al. (2004) designed a system tracking the nose and creating a vortex with an air cannon to focus smell in a particular area. The system still needs more research, but it is a way of creating novel interactions.

The reflection of focused smell on design can be seen in the project of Haque Design+Research (Scents of Space, 2004). Scents of Space (2004) is a pavilion designed with a certain airflow system to achieve selectively scented areas to create 'fragrance collages' spatially.

All these technologies create several opportunities and choices for product designers to create the language between the products and the users. Some of these technologies pose opportunities regarding the ease of use or comfort whereas others offer additional functionality or customisation opportunities. Even the material properties can be changed through interaction or the products can communicate through the changes in their materials and forms. The following process will be an illustration of the use of the LuxUX map and technology audit for design of the luxurious car interiors.

6.2 Reflection of Map of LuxUX on the Design Process

The LuxUX map created a list of principle themes with sub-themes to consider while designing for luxurious driving and also a map of relationships between these themes. Every designer has her/his own creative process to make use of the design and research materials and this section will be an illustration of the use of the map of LuxUX by the researcher for her own design process.

The PhD project brought together three partners for research and development and the initial challenge was to understand and define luxurious experience in driving context. Therefore, the main output of the research was the criteria of designing for luxury which is presented as a map including three main themes with a variety of sub-themes. This map can be used in different occasions, companies by different design professionals based on their own project briefs and challenges. However, the PhD has identified another challenge through a set of meetings and research with the partners. The challenge was to understand how the NEU interactive technologies can reflect on to the luxurious driving experience. For this reason, a technology audit carried out to create a pool of NEU technologies. The research for NEU technologies included the definitions and examples of a variety of technologies, and possible design directions especially in driving context.

The NEU technologies and the nodes and relationships in the map of LuxUX set the criteria for design. Use of both variables might create countless design proposals through the use of different design directions. For this reason, the initial step to illustrate the design process, was to filter technologies once more to identify which technologies are in line with the interest of Bentley Motors Ltd.

6.2.1 Filtering NEU Technologies

To understand the point of view of Bentley Motors Ltd. a meeting was set up to explain the NEU technologies to the partner and discuss their 'Bentleyness' – if the technologies fit into Bentley's design philosophy to achieve the Bentley experience. The meeting was held on 24th March 2017 at the University of Liverpool lasted for four hours. The initial step was the presentation of each technology with the product or concept design examples for Bentley professional to understand the potentials of these NEU technologies. During the presentations, discussions were held on each technology regarding its roles and feasibility in terms of realisation. The discussions also included the Bentley design directions and potential of these technologies to be integrated into the Bentley experience.

The last step was designed as a card-sorting activity (Baxter, Courage, & Caine, 2015) for the Bentley professional to sort all the technologies in line with the discussions and Bentley's willingness to invest time and effort. For the activity, the researcher designed icons for each technology, colour coded technologies according to their roles in interaction and organised them as a card set. The cards included the name, icon and a short definition of the technology with a few examples. All fourteen technologies organised as cards (Appendix E) and three of them are shown in the Figure 62 as examples.

Figure 62. Card examples explaining technologies

The cards have been prepared and printed before the meeting and, after the presentation of all technologies, presented to the Bentley professional for sorting activity. The contact person classified them as the technologies that they are 'extremely interested', 'very interested' and 'interested' that they would like to invest time and effort. The technologies they are 'slightly interested' and 'indifferent' are the ones that might pose potential however needs further research and implementation examples. Also, there are technologies that they do not think the implementation of these technologies would be in line with the notion of 'Bentleyness' unless proven otherwise. Those technologies are eliminated in the initial step of card-sorting (Figure 63).

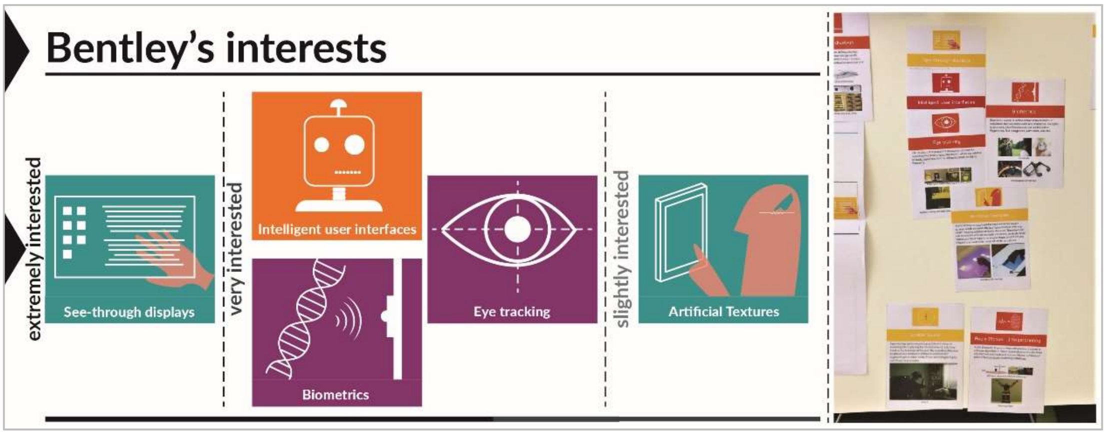

Figure 63. Bentley's interests (left) and original classified technologies (right)

After the technology audit and research on NEU technologies including the implementation (products, concepts, research) examples the researcher also made a card-sorting activity for herself. The card-sorting activity was based on the researcher's designer experience and research interests for possibilities of implementation of these technologies in a car as well as motivations and aspirations. The final step was to identify the overlapping motivations for both parties for design proposals. The result is summarised in Figure 64 showing the overlapping motivations for technologies for both parties.

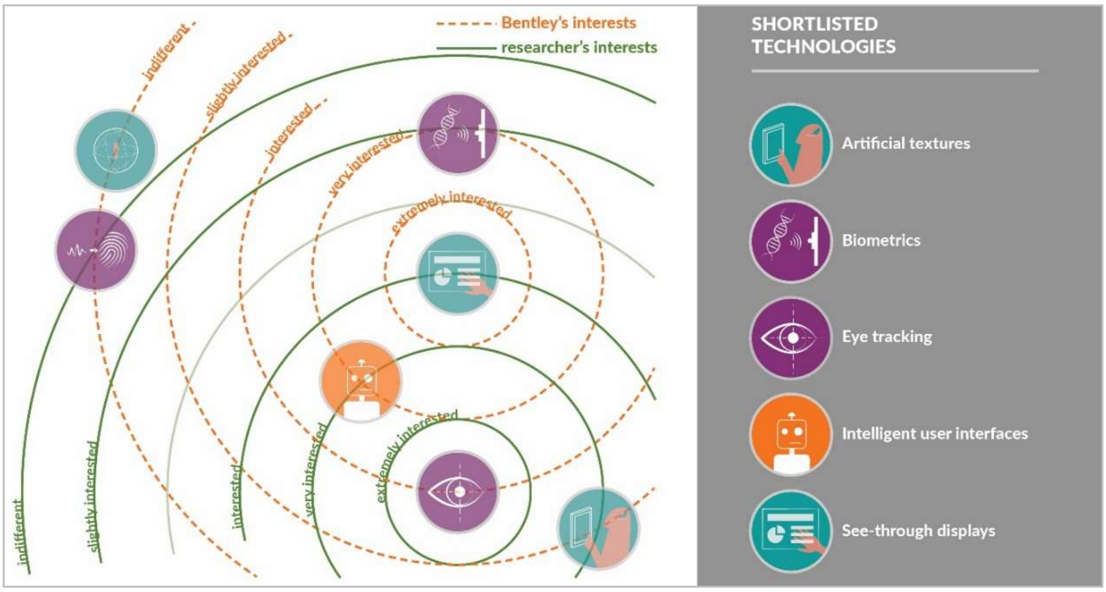

Figure 64. Overlapping interests and motivations and shortlisted technologies

As a result, five technologies were shortlisted to be used as inspirational material for building design proposals: (i) artificial textures, (ii) biometrics, (iii) eye tracking, (iv) intelligent user interfaces, (v) see-through displays.

6.2.2 Design of Three Luxury HMI Concepts

The technologies were filtered in collaboration with Bentley as the design proposals should be in line with their future visions. However, another input for filtering was the researcher's motivations and inspirations based on the technologies to bring a fresh view to Bentley's design philosophy and directions. Three concept design proposals were developed by the researcher (as designer) based on the user comments and the potentials of the NEU technologies.

The map of luxUX and the shortlisted technologies provided a matrix of variables to consider while producing design proposals for this project. However, the use of variables might change depending on the nature of the design brief. For example, the design brief might be focusing on certain clusters within the map of luxUX, areas of interaction, materials or technologies which might affect the process. This PhD was built on the perceived conflict between luxury and NEU technologies to create proposals for building luxurious experience through use of technologies. Therefore the main criteria was the descriptors of luxurious user experience (Map of LuxUX, Figure 45, p.134) and the shortlisted NEU interaction technologies. Those criteria formed a matrix as a base for the design process presented in the Figure 65.

Three concept car interiors created by making use of the matrix based on the findings of map of luxury user experience supported by the shortlist of technologies. The concepts were mainly based on criteria listed under the three clusters (i) human factors, (ii) functions and features and (iii) physical embodiment.

The first concept was named as 'The Invisible Assistant' which focused on the important points revealed in the 'human factors' cluster to support the "sense of control and performance" in the driving experience. The second concept is 'My Butler' that is based on the "sense of progress and use of skills" through the functionality of the car. The functionality of the car is based on the comments related to the 'functions and features' cluster. Finally, the last concept is about 'the physical embodiment' of the car, that is, the use of technologies for creating a 'My Unique Interior' aiming to support the feeling of exclusivity (feeling special) and providing a calm and relaxed driving experience.

SUB-THEMES	Ease of Use	Comfort	Connectivity	Customisation	Smartness	Realisation	Materials	Form
SHORTLISTED TECHNOLOGIES: Artificial textures					●		●	●
Biometrics		●		●				
Eye tracking	●							
Intelligent user interfaces		●	●	●	●			
See-through displays				●		●	●	●
MAIN THEMES	Human Factors		Functions and Features			Physical Embodiment		
CONCEPTS	'The Invisible Assistant'		'My Butler'			'My Unique Interior'		

Figure 65. Matrix of the design criteria

6.2.2.1 The Invisible Assistant

The invisible assistant can offer a comfortable, flowing experience that is supported by the car to provide the 'sense of control' and a 'calm and relaxed' driving experience. The focus of the concept is the findings of the 'human factors cluster' ((i) ease of use; feeling supported and in control and (ii) comfort; effortless driving with physical ease) and the concerns identified by the participants. The concept is built through the use of eye tracking, biometrics and intelligent user interfaces technologies.

The sense of control is closely related to human capability i.e. the ability to control and interact with the surrounding products and systems. That coincides with the definitions of ease of use; easy to understand and operate systems. One of the problems mentioned by the participants was the hierarchy and relationship between the controls and how it can be reflected in the dashboard design. The hierarchy of the controls can be reflected in their locations. In addition to location settings, the visibility of the active controls can be enhanced through interior lighting and increased contrast. Eye tracking might be an answer in such conditions by following the gaze of the driver and enlightening the area as well as increasing the contrast through backlighting (Figure 69**Hata! Başvuru kaynağı bulunamadı.**). This way, the controls would become more visible and this could lessen the eyes off time especially in darker driving conditions.

Figure 66. Tracking gaze of driver

Another concern about the locations of the controls is the reach and position of the driver, especially for labour-intensive tasks such as address entry or changes in directions. The main interaction area in cars is moving closer to the driver to keep her/his hands on the steering wheel and eyes on the road. Laser projection technology makes it possible to turn every surface to an area of interaction through the projection of the controls and the finger trackers can be used to understand the input. The steering wheel controls can be projected on the predefined areas for interaction which would make the interaction easier also keep the drivers' glance and hands on the steering wheel (Figure 70**Hata! Başvuru kaynağı bulunamadı.**). The central position of the controls would also answer the driving on the right-hand side problem for UK drivers especially for tasks requiring precision (i.e. address entry through touchpad).

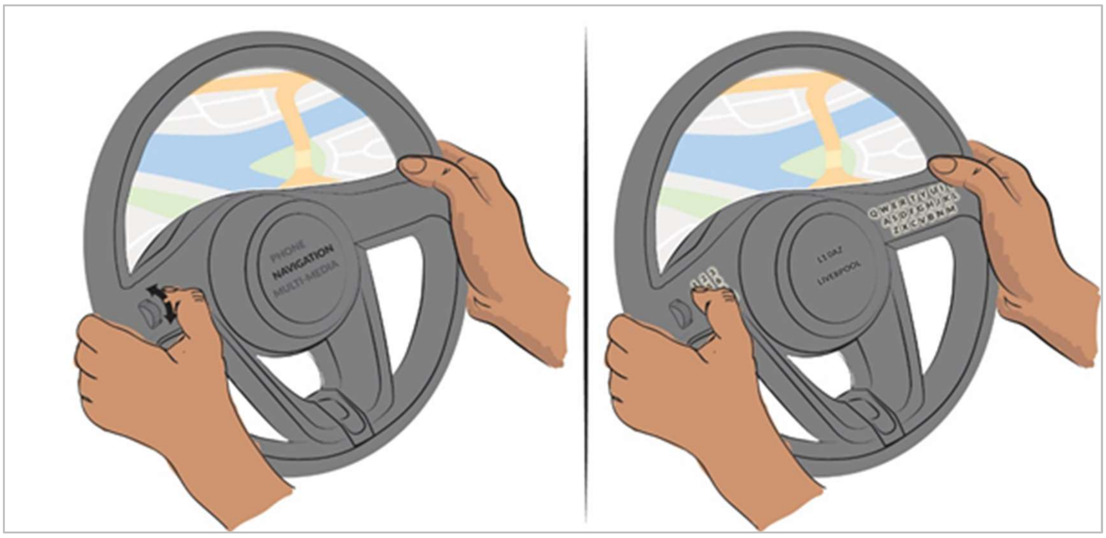

Figure 67. Steering wheel controls for keeping flow of glances

The cycle of input and information provision is quite productive for designers as it involves different modalities and possibilities. However, this cycle could also cause confusion and frustration. Information presentation within car interiors should be quite effective in terms of providing the most information to the driver within a limited timeframe (such as a 1-2 second glance of the driver). The main confusion in this cycle arises from the inconsistency in terms of the location of the information and controls. Eye tracking technology could answer this problem and could provide the co-location of the information and controls within the limited area by waking up the controls and information that the driver is looking at.

In terms of comfort, the main issue mentioned by the participants was the flow in terms of warmth in car areas such as seating or the steering wheel. A welcoming car should be cosy in terms of warmth especially in cold winter days entering into a warm car and touching heated steering wheel can become quite desirable and welcoming. Intelligent user interfaces can also participate in this experience in collaboration with biometrics. The car system generally depends on the settings provided by the driver. However, detecting the body temperature of the driver is possible through biometric temperature sensors. The body temperature information and the weather information together could create and maintain the optimum temperature settings within the car even without the user having to asking for it. The balance between these two could provide a smooth transition from cold to warm or vice versa.

The Invisible Assistant system offers ease of use and supports the sense of control through the flexibility it provides for the location of the controls, the emphasis on the important areas of interaction and providing closer controls for laborious tasks especially during driving. The aim of the concept is to keep the flow in terms of visual organisation, the glances of the driver as well as the tactile sensations through warmth.

6.2.2.2 My Butler

The concept of “butler experience” (P15) has been mentioned in the interviews and some defined this experience through “concierge” (P14). These concepts are built on understanding what the user needs/wants and supporting these tasks without any disruptions to the experience. Such as the famous butler Alfred Pennyworth (McMillian, 2014), that we get to know through the Batman series, taking care of all the details and making all the necessary arrangements even without Bruce Wayne asking for it with his distinctive sarcastic and cynical attitude. This is a flowing experience that directs the ‘master’ to focus on the actual experience that she/he would like to achieve which might be reflected in the driving experience through the use of NEU technologies. Bentley interpreted this by placing a holographic butler into the Bentley car in “the future of luxury concept” (Golson, 2016). This butler can make recommendations and reservations on your behalf and can be interacted with as in the example of virtual assistants Siri and Cortana simply by asking.

The ‘My Butler’ concept is based on the findings of the ‘functions and features cluster’ ((i) customisation; driving joy through personalisation, (ii) smartness; efficient, time-saving HMI looking after the driver and (iii) connectivity; offering a flowing experience through choices of platforms. The main aim is to create a driving environment for drivers to ‘use their skills’ in collaboration with their cars, reflect their desired experience onto the car and maintain ‘the sense of progress’ through smartness.

Connectivity is quite useful in terms of customisation for decreasing the number of steps to customise the car settings. Personal devices (phones, tablets) can be used as a base for identification as most of the users already personalise their devices. The personalised details can be reflected in the car HMI system through a designed application. The initial connection would ask the driver questions on certain HMI components such as the screen organisation, which applications to include, or even the mood lighting details. For the following journeys, the system would automatically configure itself accordingly.

Customisation is the main component of the luxury car industry. Even from the start of their production they offer options to the drivers before purchase to customise their interiors through material and texture choices. Through the driving experience, the HMI could also offer activity-based customisation preferences. Alternative driving modes are crucial for setting up a connection between the driver and the car, however, it is generally located on the central console. It might be more intimate if it can be located on the steering wheel and activated through the touch of the driver that is special to him/her. The steering wheel can be accepted as the heart of the driving experience. A gentle palm touch on the steering wheel could activate the driving modes menu. The driving modes could be reflected on the fingerprints which are providing the unique settings of the driver for each mode. After activation, the driver can throw the mode choice on the HMI for it to change accordingly in terms of visual representation and variety of information Figure 68.

Figure 68. Exclusive driving mode choices

Information, as the second step of the interaction also creates possibilities for new design routes. There is a variety of information presented to the driver in different conditions some of them are neither necessary nor wanted by the driver. Even though the digital content provides flexibility in terms of locations or visual representation (colours, size, etc.) as in the example of mobile phones, this is not reflected in the screen-based information in cars. Scenarios based on driving conditions might require different information and interior organisation in terms of the location of the information. While driving in an unknown area for touristic purposes the information would be different compared to driving for work. Also, the timing and location of that information are crucial for the experience, for example, when driving in a touristic area the driver might want to project information on the head-up display to get information about the surroundings. On the other hand, the driving for work scenario driver might ask for the HMI to become invisible or in the case of receiving an email or a message, she/he would like to see the information on the head-up display. Providing the flexibility of changing the location of the information through gestures might become quite useful in these conditions. The ability to control the amount and the location of the information would provide the desired experience (Figure 69). The integration of the see-through displays within the car would make interaction easier and more convenient and keep the flow of glances within the driver interaction area.

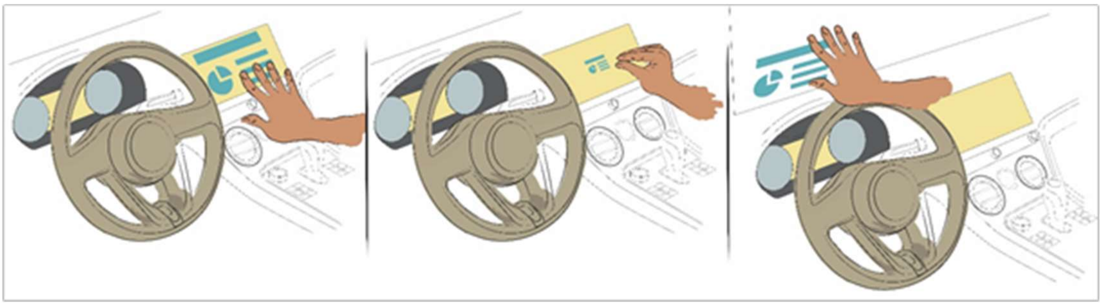

Figure 69. Changing location of the information

Car interiors are equipped with different input and output modalities however, the change in the modality is not in relation to context or the user. Intelligent user interfaces support context-aware systems through the use of several sensors which might be reflected in the input and output preferences for the drivers. For example, in the scenario of driving with friends or with kids, creating a social experience within car would make driving more complicated and information provision hard to track. Therefore, in a scenario of social interaction and navigation within the car, the settings might get aligned with the social experience through a change in modalities (Figure 70). The use of artificial textures on the steering wheel instead of an audio output to tell the driver where to turn might create a silent but effective information provision. Textures in terms of intensity and frequency are a subtle way of conveying information to the driver without breaking the social experience or waking up the kids sleeping in the back seat.

Figure 70. Information provision modes based on context

Finally, the characteristics of the car while providing information to the driver could affect the relationship between the car and the driver. Audio information provision is generally criticised because of its unnaturalistic character that fails to set up an inter-personal level of communication (Braun, Mainz, Chadowitz, Pfleging, & Alt, 2019). Smartness could become a solution for this to set up a learning voice assistant that understands the user’s way of using the language and to develop a characteristic speech ability based on the data. Another solution mentioned during the interviews (P27 - 10) was choosing from a bunch of characters and even the voice of famous figures could build up a personalised experience with the voice assistants.

The butler concept is based on customisation as well as building up a characteristic for the HMI through user choices and smartness. The reflection of the butler concept within the interior is not obvious as the main intention is to change the experience through intangible features like connectivity, smartness, and customisation. Even though the car interior remained similar to the commercial model in terms of physical embodiment, the experience it offers can be personalised through various digital solutions.

6.2.2.3 My Unique Interior

One of the main components of luxury perception is the physical embodiment details that user interacts with visually, tactually and audially. Even though the physical embodiment details are the expertise area of luxury car companies through the use of materials, craftsmanship, and precision they are challenged by technology. The size of the screens and the number of controls are increasing inevitably considering the amount of information that a car HMI include. The population of controls and the size informational screens are concealing the material qualities and craftsmanship that communicate luxury. The heritage and technology contradiction can again be reduced through the use of subtle technologies. The aim of “my unique interior” is to provide the interior details that the user selected during purchase without any visual disruptions. To achieve this technologies with subtle characteristics can be embedded into car interiors without breaking the visual flow of the materials and realisation details.

The concept is based on the findings of the ‘physical embodiment cluster’ that is stripping off the car from all the HMI elements and offering a fluid interior through wood and leather. The physical embodiment cluster includes comments about (i) materials; for feeling of opulence and refinement, (ii) realisation; the wow effect and feeling of expensiveness, (iii) form; excitement and visual flow through integration. The flow is mainly broken by the screen that is located on the wooden dashboard and see-through displays can overcome this disruption by carrying all the information onto the head up displays. Windscreens have the ability to turn into information screens and present a variety of details to the drivers. Therefore, the see-through displays can bring back the flowing wooden dashboard experience (Figure 71).

Figure 71. Flowing wooden dashboard without central screen

Controls can also become distractions for the experience from time to time. Dynamic touchpads (Figure 72) can be used as tactile touch screens with some areas morphing according to the task that the driver is working on. This can provide a smooth and sleek area that acts according to the tasks and provides the driver with tactile feedback about the controls.

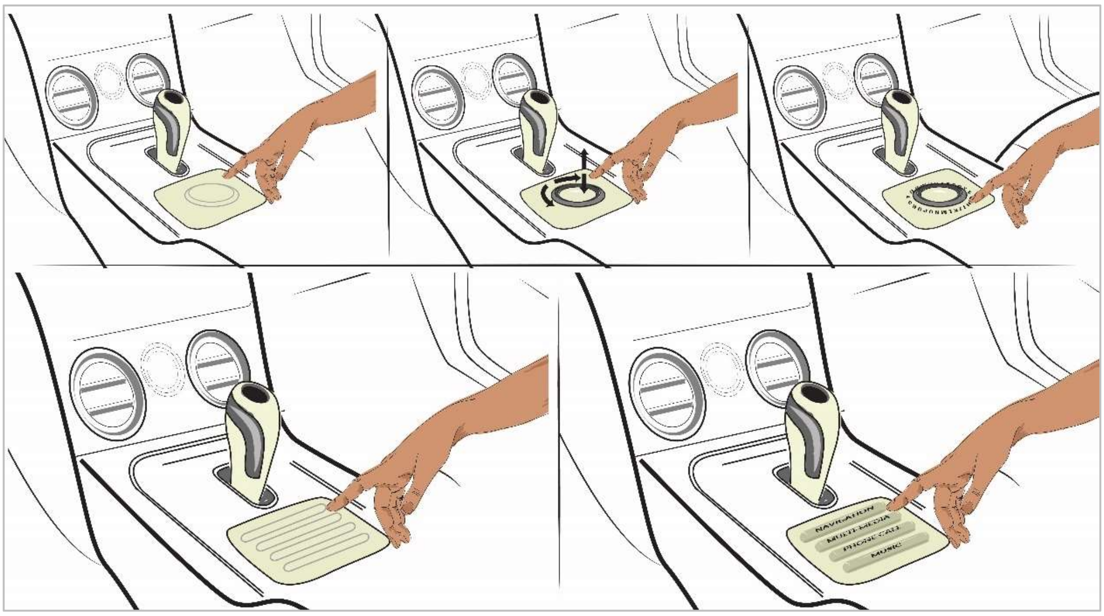

Figure 72. Use of dynamic touchpad

The HMI system with all the information and controls can become a diversion for drivers. However, especially luxury cars would like to direct the driver to the performance and driving joy. The participants mentioned the ability of HMI to become invisible in certain contexts where they do not want to pull or be pushed by the information and instead focus on the activity of driving. For this reason, in this concept there is not much information or control located strictly on the dashboard, the whole organisation can be flexible. Gestures can become a natural way of making the HMI system disappear as in Figure 73. The HMI can become active or inactive with a gesture that can provide a performance-focused experience.

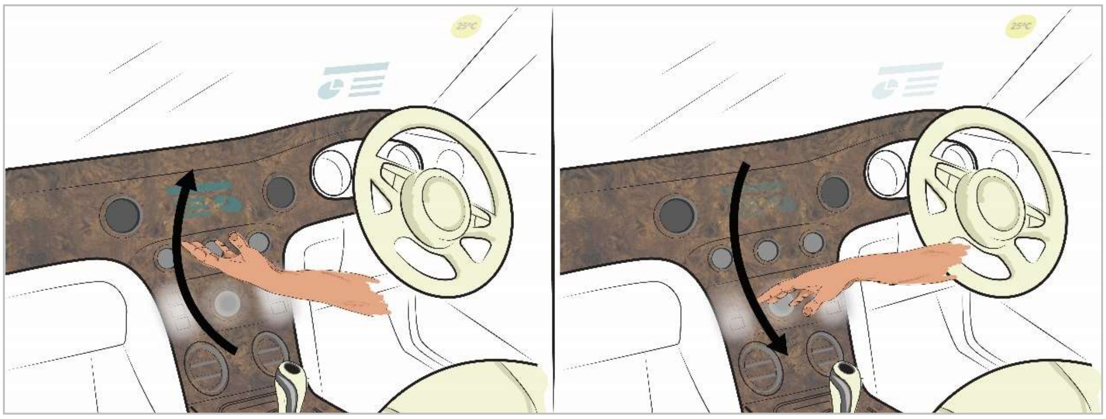

Figure 73. Use of gestures for waking up / closing down the HMI system

The settings for volume control and air conditioning require circular action for more precision and are generally controlled with knobs. A steering wheel enhanced with artificial texture and connected with the information presentation on the windscreen display (WSD) can offer an experience of controlling these tasks through circular movement without taking the drivers' hands off the steering wheel (Figure 74). The artificial textures can be activated with the menu options and can increase in terms of intensity and frequency for increasing the sound or the temperature and vice versa.

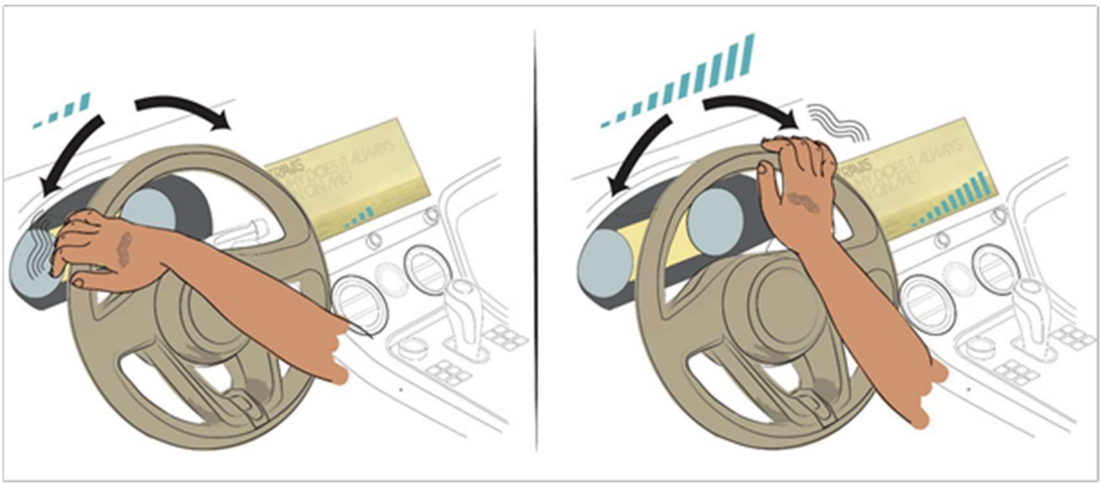

Figure 74. Volume settings through steering wheel gestures

My Unique Interior concept radically removes most of the physical controls and information and presents them virtually for achieving a flowing interior, highlighting the materials and realisation details. These interior details can be enhanced through the use of analogue components and elements for intensifying the effect of heritage and craftsmanship as well as keeping the surprise and delight effect by offering virtual content for interaction.

These concepts were just for illustrating possibilities for the creation of luxury car interiors through the use of technology. The technologies are mainly designed for functional purposes however, this is not enough for communicating the luxury to the user. The interpretation of technologies with their visual (i.e. intensity, contrast, quality) tactile (i.e. frequency, intensity) and auditory (i.e. sound design, characters) properties could also provide refined experiences causing the wow effect on the users. This interpretation process requires further input other than a designer’s touch which can be gathered through research. In this PhD, the research provided the criteria for designing for luxurious experience. As, one of the challenges for luxury was identified as technology adoption the second criteria was set as NEU interactive technologies. Two set of variables built a matrix that can be used with different interpretations by different designers and design teams.

The design process is a cyclic process that generally starts with collection of data and inspirational materials, sketching design proposals and building design concepts, evaluation of the design proposals through mock-ups and prototypes. The process iterates after the evaluation phase and revisions are made based on the data gathered through evaluation. So the evaluation process is another important phase of commercialisation of the design proposals. The next chapter of the PhD will focus on the evaluation phase especially in terms of interactive technologies and new prototyping tools (i.e. simulation tools and technologies).

CHAPTER 7

PROVISIONS FOR VIRTUAL PROTOTYPING OF LUXURY AUTOMOTIVE HMI

This final study of the PhD study is built around the fact that traditional product modelling and testing tools (i.e. foam-clay mock-ups, working prototypes) are increasingly being replaced by simulation technologies. The development of these technologies creates challenges as well as opportunities for product design teams. This study was carried out as a workshop to understand these challenges. The simulation technologies are highly utilised in the automotive sector for evaluation and assessment of new technologies regarding their potential for integration into cars. Simulation is useful both for mimicking these technologies and context that they will be used in and create a safe environment for assessment. Even though the main focus of this PhD is luxury driving experience the aim is to create guidance and inspiration material for designing luxurious driving experiences. For this reason, the simulation technologies as the evaluation step for design proposals are quite important for this process. In order to include guidance on the assessment technologies, a workshop has been designed that was carried out with simulation professionals on NEU technologies and how they can be mimicked in a simulation environment. The workshop created a discussion setting for professional to share their ideas and proposals for the simulation of multimodal experiences. A shortlist of fourteen NEU interactive technologies was determined through a technology audit (see 6.1. New, Emerging and Unusual Interactive Technologies), followed by the recruitment of four experts from the Virtual Engineering Centre to evaluate the simulation of these technologies. The evaluation was based on pre-set criteria regarding the suitability, availability of tools and extent of research and development required to simulate the interactive technologies, within a context of new product design and development

The aim of the study was to gather experts' opinions on how (and whether) simulation can be used to digitally prototype technologically advanced in-car interactions within the human-machine interface (HMI) of a vehicle. The results of the evaluative workshop are useful for assessing the feasibility of simulating various interactive product technologies with available tools and methods, as well as possibilities for near future scenarios and their anticipated impact.

7.1 Methodology

At the commencement of the study, a large pool of new technologies was researched through online sources (academic studies, technology blogs), and then filtered with the supervisor regarding their potential for integration into an in-car environment. A shortlist of fourteen technologies was reached, along-side a classification regarding their role in interaction as explained in the Section 6.1. New, Emerging and Unusual Interactive Technologies. The shortlisted technologies were (i) input (eye tracking, audio fingerprinting, tactile touch displays, biometrics, smell capturing), (ii) input-output (flexible displays, shape-changing interfaces, intelligent UI, deformable displays), and (iii) output technologies (texture and softness changing interfaces, see-through displays, artificial textures, spatial sound, focused smell). Following the audit an extensive document with definitions of the technologies and example product applications and concepts was shared with the workshop participants one week prior to the session, to help them familiarize themselves. The workshop was carried out in the Virtual Engineering Centre facilities, Daresbury Laboratories on 9th March 2017 and lasted approximately two and a half hours. The workshop structure is summarised in Figure 75.

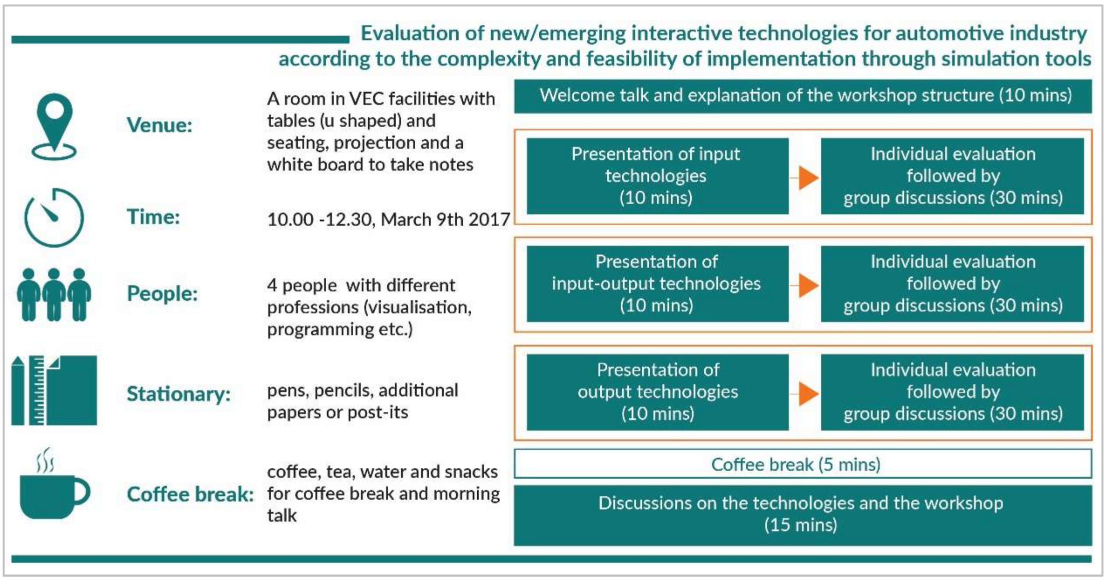

Figure 75. The structure of the workshop on evaluation of NEU technologies from simulation perspective

During the workshop, the researcher presented the technologies again so as to jog the participants' memories. Besides the technologies and definitions, the pre-workshop document also included technology trends (Figure 76, top) and possible locations (Figure 766, bottom) (fixed, semi-attached, on-body, fully mobile) for the technologies in a driving scenario, as a prompt for participants to keep in mind.

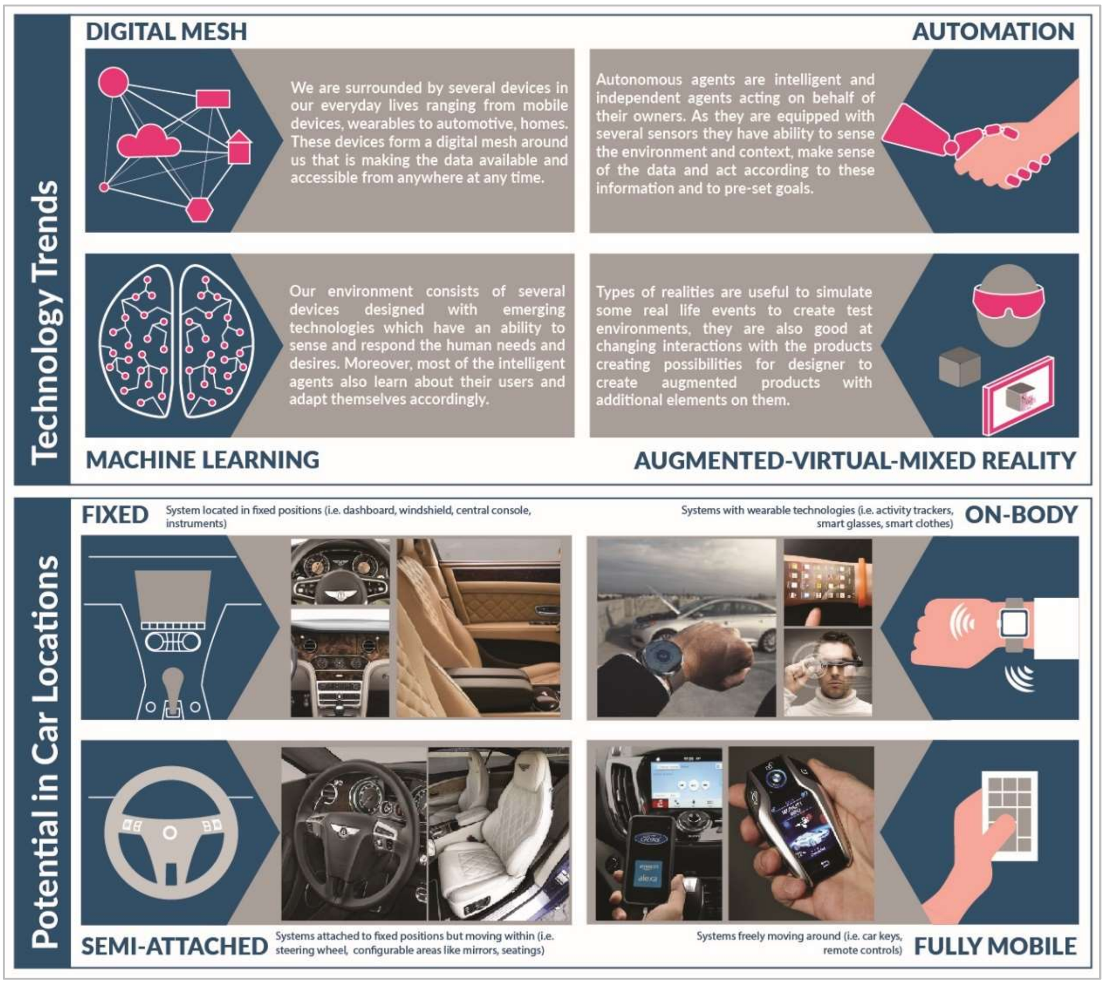

Figure 76. Technology trends and potential in-car locations for technologies

During the workshop participants were requested to independently make a professional assessment of the interactive technologies, under the overarching subject of how to create a simulation of the technologies in a digital environment. They were given individual evaluation sheets for each technology group (input / input-output / output). The criteria to evaluate the technologies were set as (i) suitability to reality levels, as augmented reality (AR), virtual reality (VR) and mixed reality (MR); (ii) availability of hardware/software (bespoke/R&D, commercially existing, or existing at the VEC); (iii) feasibility with regard to R&D time/effort and cost; and (iv) expected impact of a 'successful' simulation of the technology. The independent evaluation process was followed by a group discussion about the technologies, with each participant contributing their own perspective. The icons and technology cards designed for the card-sorting activity (see 6.2.1 Filtering NEU Technologies) were utilised for the evaluation process. All the cards, the stickers with icons of technologies and the criteria boards were prepared and printed before the workshop to facilitate the process. The workshop setting and original evaluation sheets can be seen on Figure 77.

Figure 77. Workshop setting and evaluation process

The workshop was video recorded with consent, and then transcribed for analysis. The detailed results of the evaluation of technologies and transcribed data are explained in the following section.

7.2 Results

The recorded workshop discussions and materials were collated and analysed, with an aim to identify the collective challenges and potentials of simulating the shortlisted in-car technologies. The results are summarized under three titles: Input Technologies, Input-Output Technologies and Output Technologies.

7.2.1 Input Technologies

These technologies are used to give actions and information to an HMI system corresponding to user tasks and goals. Five input technologies were shortlisted and the evaluation of these technologies is summarized in Figure 78.

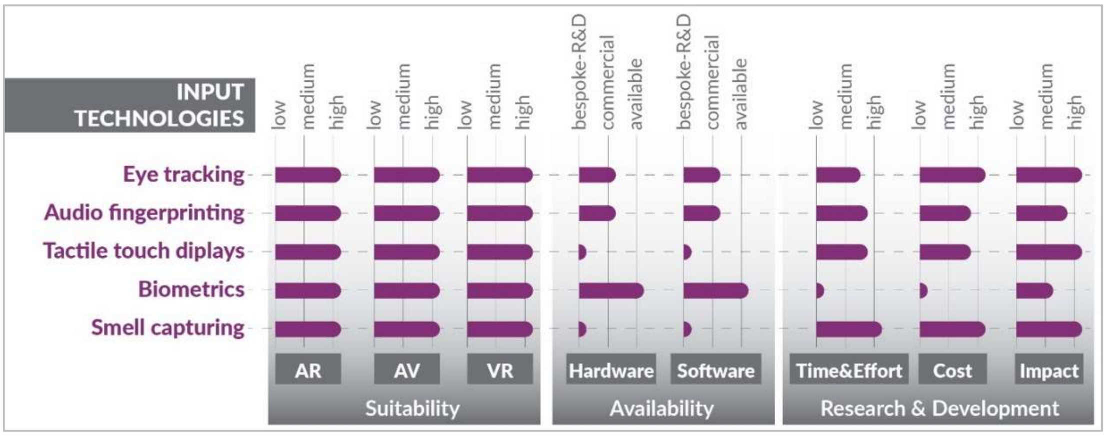

Figure 78. Evaluation of input technologies

Some input technologies were considered to be possible to simulate, even in the absence of the real-life sensors associated with them, using 'wizard of oz' prototyping methods. For example, biometric input for identification is just a single step interaction, which can be mimicked simply by knowing who the user of the simulation is, with the simulation researcher inputting a setting accordingly. On the other hand, if the case was to simulate a product changing its interface ac-cording the heartbeat of the user, this would require sensors to continually gather biometric information constantly making the process complicated and costly.

Another important point about the input technologies, in relation to a usage scenario, is the output that is expected to follow or be associated with it. For example, the input may consist of identifying a certain smell, whilst the corresponding output may, for example, be a change of interior lighting (a visual response, relatively easy to simulate). Alternatively, the smell sensor may trigger changes in comfort settings of the vehicle seating, requiring more time, effort and cost to simulate. The level of precision or resolution for input sensing emerged as an important point and challenge. Demands for higher precision lead to a necessity for increased time, effort and cost when creating a simulation. For example, if an eye tracking scenario requires precision (e.g. locating small buttons only millimetres apart), workshop participants mentioned it will require longer time (to code and execute) and more capable and expensive eye tracking hardware and soft-ware solutions. With less precise demands, for example tracking the changeable focus from one HMI display to another, participants recommended head tracking as being a sufficient input source. Design criteria such as the location of interface controls and technologies places certain demands on simulation possibilities and processes. For example, for tactile touch screens it is easier to simulate tactile elements on a fixed-location screen, but far more challenging to map multimodal elements (visual, tactile) on a mobile screen, especially in mixed reality simulations.

7.2.2 Input – Output Technologies

Input-output technologies combine user actions and the input of information with the output of feedback, through a single underlying means. Four such technologies were shortlisted, and the evaluation of these technologies is summarized in Figure 79.

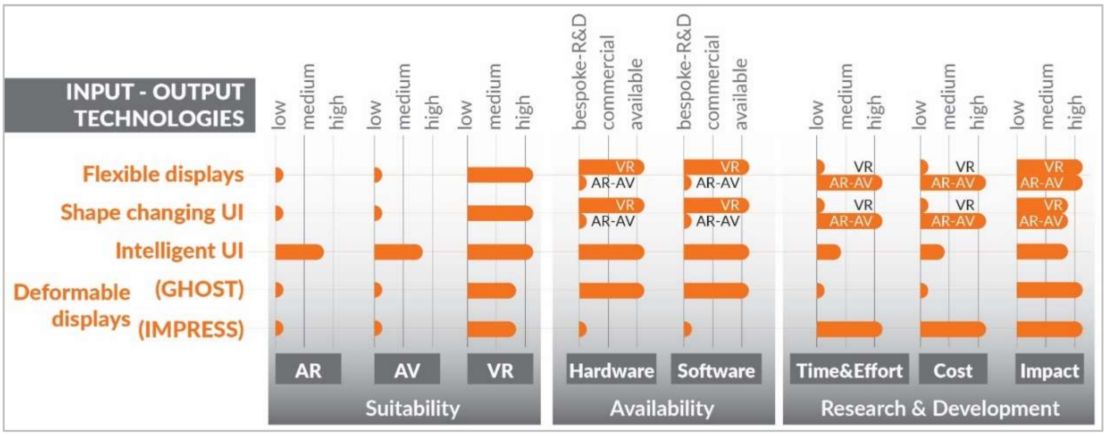

Figure 79. Evaluation of input - output technologies

Input-output technologies, with their inherent dual functionality created an evaluation challenge for the workshop participants. For example, in flexible displays the input is the flexible materiality of the display caused by a force from the user, requiring haptic feedback from time to time that is notoriously challenging for a VR environment. However, the output is visual, where mapping a changing image onto a flexing surface is not a major challenge in a VR environment. So, the evaluation process demanded more scrutiny and detail on materialistic aspects of the technologies than had been anticipated. The suitability for different simulation environments was a point of major discussion while evaluating these technologies. Some participants regarded the technologies as suitable for VR but not suitable for mixed reality options, thus affecting recommendations for hardware, software, R&D time and effort. Participants suggested that for a detailed assessment of the technologies, it would be better to choose (fix) the simulation environment (AR, AV, VR), since it would focus the discussion on specific requirements and possibilities rather than general comparisons.

The role of particular interactive technologies can change from application to application (e.g. between different interfaces, products, etc.), complicating the evaluation process. This is the case, for example, with the deformable displays exemplified with two different products GHOST (Jansen, et al., 2015) (3D representation of information) and IMPRESS (Impress - flexible display, 2009) (changing content in harmony with the deformation of a display). Even though principally the same technology has been used in both products (display deformation), the end experience is quite different. GHOST changes its shape according to 2D hand movements, which was regarded as relatively easy from a simulation perspective, since it requires tracking of hands only in a planar movement. On the other hand, IMPRESS makes use of the anatomical potential of the hand and requires precise tracking of the hands and fingers to understand exact movements in 3D space. GHOST was considered to fit within the scope of simulation using relatively simple existing equipment and software combinations with little time and effort. However, participants stated that simulation of IMPRESS would require intensive detail about hand position and posture tracking, accompanied by specialist high-precision tracking hardware and soft-ware.

7.2.3 Output Technologies

These technologies provide feedback and feedforward information to the user of a product. Five technologies were shortlisted, and the evaluation of these technologies is summarized in Figure 80.

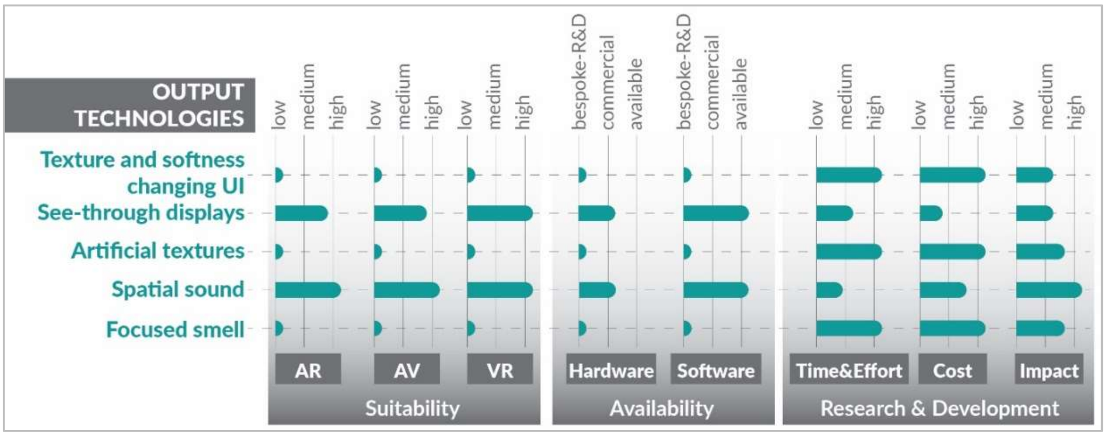

Figure 80. Evaluation of output technologies

The convincing simulation of output technologies based on modalities other than visual or audible remains difficult to achieve. As simulation environments are heavily built around visual stimuli, visual output as a research area has received the greatest attention and has advanced the most with regard to equipment, soft-ware and feasibility. The general observation from the workshop was that although numerous simulation approaches to tactual sensations are possible (touch, haptics, kinesthetics, proprioception), the associated hardware is often relatively invasive or cumbersome. For these reasons, a perpetual question in the workshop regarding feasibility of non-visual technologies was "is it worth simulating?" instead of "how can we achieve this experience in a simulation?". For ex-ample, in the case of focused smell, experts asked the question "can you VR smell?". Realizing 'real smells' (e.g. leather, deodorants, coffee) into an environment, instead of synthesizing a given smell from a range of 'smell ingredients' was regarded as far easier and cheaper. Challenges regarding the simulation of spatial sound (e.g. multiple point sound sources, rather than simple left-right stereo or monoaural) were raised. First the necessary steps for recording spatial sound must be in place, followed by the playback of recordings during simulation. Use of sound in general is relatively simple, with a basic choice between speakers and headphones, but recording of spatial sound requires specific equipment and experience, which makes its implementation in simulations generally more challenging.

Finally, a special note was mentioned regarding see-through displays. Although innovative from a product application point of view, see-through displays were rated as having low impact on simulation possibilities. This is because their simulation is straightforward and without major challenge. It is a case of an inter-active technology being far easier to simulate digitally than realize materially in the real world.

7.3 Discussion

The evaluation study was productive in surveying what is technically possible (initially in Virtual Engineering Centre as well as other simulation facilities that participants know of) regarding the simulation of user-product interactions reliant on emerging interactive technologies. One challenge of the study was to concentrate experts on simulation possibilities other than VR. The majority of VEC's experience is in sectors where simulation is carried out using VR solutions. In product and automotive design, the potential for mixed and AR solutions has been repeatedly pointed out, being potentially easier to achieve, compatible as an additional 'layer' onto other modelling methods used in design (e.g. 3D mock-ups, 2D interface mock-ups) and more portable/flexible.

The study revealed a list of points to consider for setting-up a study to evaluate new interactive technologies, regarding their feasibility of simulation for product evaluation purposes. The pre-set criteria (suitability, availability, R&D) are interconnected. The evaluation of suitability to different levels of reality was made considering available hardware and software. Availability decisions are affected by the intended level of reality, since mimicking a technology in AR requires different equipment than VR, which may or may not be available locally or commercially. R&D evaluation is based not only on the availability of the hardware and software, but on the perceived investment of effort and resources to achieve a successful simulation. More precise follow-up evaluation for all three criteria must take into account contextual factors as follows.

Details of the usage scenario (in which the interactive technology is applied):

- the role of the technology (input, output etc.)
- the properties of the product (mobile, fixed etc.)
- length of interaction (immediate vs. long-term responses)
- scenario details (the expected input and output details, user id, open scenario etc.)
- context of use (daytime, night-time, alone, collaborative, etc.)

Level of required simulation precision, as defined by:

- mapping (mapping visuals on a mobile or fixed element)
- tracking (tracking one or multiple elements)
- resolution (visuals on a small or large screen)

Outside factors:

- range of available equipment
- experience level of the participants (participants specialized in VR might overlook or underestimate other options; aim for breadth in expertise)

The study has provided initial answers to the question: to simulate or not to simulate? To obtain results that look more deeply into the feasibility of simulating a particular interactive technology, the above listed points should be brought into the frame. All reality levels have their own challenges and opportunities. For example, mapping of simulations onto elements of the real world can be a challenge for mixed reality, but not for VR. On the other hand, tracking is a significant challenge for VR, which can be overcome through the use of physical objects in mixed reality. Lastly, workshop participants assessed the impact of successfully simulating most of the shortlisted interactive technologies as medium-to-high. This provides evidence of a common point between communities interested in integrating new interactive technologies into automotive and product designs, and communities interested in simulating such technologies for evaluative and demonstrative purposes.

CHAPTER 8

DISCUSSION AND CONCLUSIONS

The automotive industry is pioneering in many research areas, ranging from materials, engineering and interactive technologies to prototyping and testing environments. This provides a satisfying research environment for many design researchers to integrate different points of views into a research project. This PhD has integrated the concept of luxury, designing for interaction, and use of simulation technologies for evaluation of NEU (new, emerging and unusual) interactive technologies in the context of automotive HMI systems. The initial motivation for the research was to understand the drivers/customers of luxury automobile brands, alongside a better characterisation of the concept of luxury in the automotive sector. Furthermore, the research has sought to confront the challenges and potentials raised from a design perspective, thereby complementing the understanding of luxury from engineering and marketing perspectives. The literature review supported these initial motivations by revealing the fact that the concept of luxury is studied generally in a marketing context, and mostly with an emphasis on physical embodiment details. That approach is now being challenged and its relevance questioned by the presence and introduction of new interactive technologies, which are becoming integrated into everyday products as well as cars. For this reason, as well as revealing the dimensions of luxurious driving experiences, the research was directed at understanding the likely positive and negative implications of NEU interactive technologies on such luxurious driving experiences – taking a 'research for design' approach to reach useable and actionable results for automotive design teams.

NEU technologies have brought challenges not only for design but also for the assessment processes of design proposals. The automotive sector is built on user research based around physical and cognitive ergonomics, with research especially directing design decisions on driver and passenger safety. Therefore, evaluation processes are crucial for the automotive sector in terms of interior design and HMI development. New evaluation technologies such as virtual, augmented or mixed reality applications are supporting the evaluation environment through mimicking driver-HMI interactions and reproducing contextual elements. However, these technologies also are found lacking in certain aspects, such as mimicking fine details found in physical embodiment and multisensorial experiences. For decades, these fine details have been primary communicators of luxury, bringing together precision, craftsmanship, and expertise. These criteria make the evaluation process more complicated in terms of simulation technologies and luxury relationships. This fact created the secondary base for the research, which was to determine the nature and potentials of digital simulation to reproduce the experiences of NEU in-car interaction technologies, as well as serve as an evaluation medium for luxurious driving concepts.

The PhD was carried out with three partners (University of Liverpool, Virtual Engineering Centre and Bentley Motors Ltd), who made valuable participation at specified periods of the research programme. The contributions of this multifaceted PhD will be explained in the following section.

8.1 Research Implications and Contributions to Knowledge

The main contribution of the research is revealing and explaining in detail the descriptors of luxurious automotive HMI experience. To define the luxurious experience, the research commenced with a literature review on luxury and products. The motivation for choosing the research area was based on the findings of the review, which revealed a gap in the academic literature and practice-oriented publications regarding what is and how to design for luxury. The review was nurtured mainly by marketing research, identifying four luxury values (financial, symbolic, functional and experiential) which were combined with principles from UX literature to understand how luxury might be achieved and considered in product design. ***This provided the foundation for the research: a value-based approach blending marketing research theory with user experience theory, specifically to understand and evaluate the luxuriousness of products.***

Following this, further clarifications were needed to reach an understanding of what luxury automotive HMI might comprise. The immersion method (Jordan, 2000) was used to reveal automotive control and information types as well as new trends and directions in commercial luxury automobiles. ***The results of the immersion study revealed: (i) the reflections of technologies to car interiors as changing dashboard elements, (ii) the rise of customisation and its applications in car HMI systems and interiors, (iii) the digitalisation of information in cars and the relationship between physical and digital content of car HMI systems, and (iv) the cues and clues on how luxury is communicated in cars through HMI systems.***

The third step of the research was designed for building a deep understanding of luxurious interaction from the luxury car drivers' point of view. A qualitative research methodology was pursued consisting of semi-structured in-car interviews (n=28) followed by an extensive data analysis process spanning quantitative and qualitative methods. ***This study contributed a comprehensive new understanding of: (i) the foundations of luxurious driving experiences, (ii) design decisions that can support the communication of luxury through human factors, functions and features, and physical embodiment details, (iii) trends and possible directions that might be influential on car interiors and HMI in the near future, as well as (iv) design criteria for luxurious driving experiences.***

The fourth step of the research was to understand which NEU interactive technologies might revolutionize car HMI systems in the coming years, gathering and generating predictions for how these technologies will change car HMI systems. ***This study contributed an extensive review of NEU interactive technologies posing potentials and challenges for integration into the luxury car sector.*** The review was followed by design proposals generated as inspiration material, ***illustrating through the development of three HMI concepts how the design criteria (provided in the previous study) can be integrated with NEU interactive technologies, as well as the possible effects of NEU interactive technologies on car interiors***.

The final study of the research investigated the potentials and limitations of digital simulation for assessment of luxurious car HMI systems based around NEU interactive technologies. ***This study established: (i) criteria to consider while choosing between different evaluation / simulation methods and technologies*** (VR, AR, MR, prototyping, or use of physical mock-ups rather than simulation), (***ii) criteria for creating an effective simulation environment in relation to the characteristics of different technologies*** (based on different sensory modalities, application areas, etc.), and ***(iii) scenario details to consider while setting up digital evaluation environments.***

In summary, this PhD contributes to knowledge by identifying future directions for car HMI systems, proposing new design criteria and maps of relationships between constructs of luxurious driving experiences and interactions, and has illustrated how theory and research can be aligned and reflected onto the design process as well as the car interiors through an applied study. In addition, the PhD has provided criteria for setting-up effective digital environments for the purpose of evaluating driving experiences where integration of NEU interactive technologies and luxury experiences is of high importance.

8.2 Answers to Research Questions

The PhD research was concentrated on enhancing and improving car HMI systems through careful design, intending to deliver luxury driving experiences. This motivation became the main research question:

MRQ - How can we design automotive HMI to deliver luxury driving experiences?

However, the literature review revealed that the initial step for improving car HMI aiming for a luxurious experience required preliminary studies to first uncover the descriptors and definitions of luxurious driving experiences. This brought the sub-research questions as follows.

SRQ.1 - What are the descriptors of luxurious interaction in relation to automotive HMI?

Three additional questions were connected to this sub-research question:

- How do people define luxurious HMI in their own cars?

- What kind of design features communicate luxuriousness to the driver in a car?

- How can we reflect NEU (new, emerging, unusual) interactive technologies to car interiors intended to deliver luxurious interaction?

To answer these questions, an initial field study carried out in collaboration with Bentley Motors Ltd. was made for understanding the luxurious details of car HMI systems through assessment of commercial luxury car models. The research revealed important insights on luxury HMI systems as described below.

- The observations on the reflection of technologies onto car interiors and changing dashboard elements, as well as organisation based on technological developments. Examples include the location of controls and information becoming closer to the driver and defining the car cockpit by prioritising driver and driver-related controls.

- We are experiencing an age of mass customisation in every product that is provided with new technologies. The customisation trend is reflected onto cars as personalisation (for example the ability to personalise the controls by assigning functions, or the seating arrangements as the driver wishes) and configurability (for example the ability to configure visual information presentation settings based on activities, or ability to choose the modality to receive information such as visual or audio).

- The main issue that causes inconsistencies in HMI systems is the relationship between digital content and physical controls. Screen menu structures and how information is visualised should be reflected on physical controls in order not to cause confusion. The number of categories, the actions defined within the visual content (such as the action of moving upwards or circular movement as in the use of knobs) could be reflected onto physical controls to overcome the complexity of the data visualisation and physical controls relationship.

- The variety of controls (e.g. touch screen, touchpad, buttons, and knobs), duplication in control functions, the variety of functions within controls (such as multifunctional knobs; turning, pressing, toggling) could all cause inconsistencies and confusion in drivers.

Changes in HMI systems are ideally made at a slow pace, considering the 'muscle memory' that drivers build over years of experience with their cars. Therefore, all the findings of the orientation study show that presently companies are in a transition phase, in which they offer a variety of choices to their drivers in terms of locations and types of controls and information. This transition phase is tending to direct the car interiors to move all the driving content to the driver area, or even clear out the cars from controls if taking into account the prediction that autonomous driving could become widespread in the coming years.

- How do people define luxurious HMI in their own cars?

The research to reveal luxurious HMI criteria comprised semi-structured interviews (n=28) conducted with Bentley staff (mainly working on the design and development of car interiors). It was followed by an extensive quantitative and qualitative data analysis process.

The findings showed luxury experience can be defined as: feeling special, use of skills (competence), a sense of control, performance, progress, and a sense of being calm relaxed under the overarching theme of 'flow'. The findings coincide with the definition and elements of flow as introduced by Csikszentmihalyi (1991)

> "the common characteristics of optimal experience: a sense that one's skills are adequate to cope with the challenges at hand, in a goal-directed, rule-bound action system that provides clear clues as to how well one is performing" (Csikszentmihalyi, 1991, p. 71)

The uncovered descriptors of luxury driving experience are in line with the wider flowing experience definition, however the points that participants mentioned are in the context of driving and automobile experience.

- **'Feeling special'** is defined as being serviced by the car, exemplified with the 'butler, concierge or invisible waiter experience' who provide 'the masters' with their requirements even without asking and with a subtle attitude. Acting on information such as avoiding traffic and arriving earlier than others could bring a feeling of winning and exclusivity. However, the balance between patronising and subtlety can be maintained by providing an appropriate level of service.

- '**Use of skills'** is highly tied with the concept of 'appropriate level of service' in which the car becomes complementary and supportive but avoids intruding into the driver's flow. An example is providing a necessary amount of information but leaving decision-making to the driver without becoming a distraction.

- '**Sense of control'** is also related to the use of skills and the quality of information (accuracy, precision, etc.) provided by the car. This can be exemplified by the cyclic process of information provision that is providing information about the situation and also possible consequences of the decisions. A sense of control is the state of awareness about every element affecting the experience and being the person who makes the decision and takes responsibility for its consequences, based on the information.

- '**Performance'** is about what is happening under the pedal; it is about the use of skills and making most of your abilities through handling the car. This is probably the most advancedly achieved component for luxury car brands, who have been focusing on performance throughout the years. Therefore, the HMI system can assist the driver in achieving the performance that they desire by becoming an invisible waiter supporting the experience without intrusions.

- '**Progress**' is about moving constantly in terms of driving and vehicle movement. The flow of the driving experience can easily be broken by traffic jams with start-and-stop cycles. The level of service and information provision is quite useful for avoiding these situations, as participants mentioned sometimes driving further and for longer can be preferable over waiting in traffic.

- **'Calm-relaxed'** environment within a car is mainly about the physical embodiment, however it is also tied to the sense of control and progress. The physical embodiment details, ergonomics, the interior organisation can each support a calm and relaxed environment for drivers. The initial experience starts with a car through the 'welcoming seats' flowing touch without surprises (without unexpected textures or warmth). However, keeping calm and relaxed during driving is also influenced by the sense of control and keeping progress without unpleasant interruptions.

The findings also indicated how the above elements are communicated to participants through the use of concepts.

- **Relativity**; this is mainly based on personal interpretations and experience with previous products and also the effect of getting used to a car, with the vanishing 'surprise and delight effect' over time.

- **Exclusivity**; this is dependent on external factors and comparison of the car features and design details with others such as owning limited editions, and exclusive brands showing that the consumer belongs to an exclusive community. That feeling can also be supported by providing extra features without even considering the use frequency – in such circumstances, participants interpret even the possibility of using that extra feature as exclusivity.

- **Harmony and consistency**; this is about physical embodiment details such as materials, textures, and production techniques in a car, as well as the traditional approach of heritage within the models of the brand produced over the years.

- **Functionality**; this is the invisible component of luxury, that users take for granted. However, products with ill-functioning details cannot provide or maintain luxury. On the other hand, the perfect functionality does not mean luxury: it supports the utilitarian approach and needs to be enhanced with experiential details.

- **Use of/embracing technology**; this is the challenge and the possibility for luxury in future generations of car, since luxury car brands have built their reputation on being pioneers in performance which might easily be reflected in the use of technology. The use of technology can support the exclusivity through rarity, novelty and design details, as well as high quality and better service.

- What kind of design features communicate luxuriousness to the driver in a car?

The interviews were used to reveal the criteria on which people base their evaluations of luxuriousness of car HMI systems. Three clusters are effective in delivering (or detracting) luxurious experience as illustrated in the map of luxUX (see Figure 45, p.134); (i) human factors, (ii) functions and features, and (iii) physical embodiment. Under each cluster are several constructs to consider while designing for luxury automotive HMI.

Human factors concerns are the most mentioned and effective concerns in terms of facilitating the flow through ease of use and comfort. Ease of use provides a sense of control and competence to the driver, through the feeling of being supported by the car. The organisation of controls provides easy access and operation to maintain the fluidity of interaction as well as safety by decreasing the steering wheel 'hands-off' time. The design of the controls supports ease of use by providing physically effortless to reach and use controls. The second step of the interaction concerns access and manipulation of information, which can become supportive through ease of use achieved by the location, organisation, and variety of information keeping 'the flow of glances' within the car. Also, the interaction characteristics (as the responsiveness of the system) and visibility of the information (in terms of location) can reduce accidental interactions and the number of steps for achieving certain tasks. Accidental interactions cause interruptions within the driving, which become annoying as well as distractive by breaking the flow of the experience.

Comfort creates a calm and relaxed environment within the car, providing the feeling of being special. The comfort options regarding the physical ergonomics such as seating/steering wheel adjustments, reach and position provide physical ease during longer journeys. Also, a welcoming car environment can be maintained by temperature settings that provide cosiness with a warmer interior on a cold winter day. The temperature settings also create a flowing tactual experience that maintains similar temperatures on the contact areas such as steering wheel, seating or gear sticks. In addition to physical ease, the ability of the car to align with contexts can also create a comfortable environment – in which case, car settings change in response to contextual elements. An example is how the social experience within a car can easily be broken by the audio command and feedback; switching information provision to other modalities can keep the flow of the social experience within the car.

Functions and features within the car also support the flow of experience, sense of progress and feeling special through customisation, smartness, and connectivity. Customisation is a trend that is actively implemented in the luxury sector. However, the main approach is the customisation of options at the production stage (such as materials and finishes). Digitalisation has brought the flexibility of customisation through use, which can maintain the feeling of being special for the user by having the unique experience created by herself/himself. This unique experience can be based on the customisation of the physical controls which support the ease of use and comfort. Also, personalisation of the information provision such as the visual organisation or even the characteristics of the audio information contributes to the feeling of exclusivity. Moreover, customisation can be based on contextual elements (such as people in a car, the purpose or the mode of driving) providing options for interior organisation and information provision. In addition to the feeling of exclusivity, customisation can also support the performance of the car by enhancing the driving experience through creating an information-free environment. The configurability of screen-based information and HMI systems brings invisibility and subtlety in order to keep the driver solely focused on 'the things happening under the pedal'.

Smartness provides and maintains the flow through constant monitoring of the user and contextual elements and automatically making necessary arrangements or adjustments. This way the HMI can serve the driver as an invisible waiter that is aware of the drivers' needs and wants, even without asking, giving a feeling of being looked after by the car. However, the level of smartness is crucial to consider as the car might become patronising to its user, forcing her/him to act in a certain way which can contradict with the sense of control and competence. The smartness for facilitating luxury should mimic the level of service as a personal assistant, taking initiative for certain tasks but especially for out-of-routine activities leaves the decision-making process to the driver. Another luxury component that smartness could maintain is the sense of progress related to keeping a routine without interruptions. The sense of progress can be maintained by staying away from busy traffic jams or taking narrower roads for the sake of shorter distances. Luxury car drivers prefer to drive longer distances or even durations if it is able to keep the flow and stay away from uncomfortable driving conditions.

Another concern about the HMI for luxury is connectivity, which is generally accepted as a precondition for providing smartness. Luxury can be built by staying away from repetitions of activities and decreasing the number of steps for achieving certain tasks that are letting the user make use of her/his skills 'effortlessly'. Connectivity is a way of achieving this by providing information through personal devices or the cloud. Through connectivity and transfer of information between devices, the user does not need to input the same data repeatedly, which saves time and effort. Still, the ability to connect is not enough if the process of setting up the connection is laborious such as finding and carrying cables and connecting devices through intricate parts. Finally, connectivity brings the challenge of integration of the same data to a variety of systems and settings. The achievement of integration in terms of application and transferrable data affects the efficiency of the system and interaction, such that non-achievement could easily break the flow and become useless.

Physical embodiment is the most familiar cluster of luxurious car HMI, including the constructs classified under realisation, materials and form. Physical embodiment details are the main current expertise of luxury manufacturers, reflecting heritage such as the leather seating, steering wheel elements or textures and precision of metal controls. The realisation details play an important role in communicating luxury to the user, the craftsmanship and handmade details support the feeling of exclusivity through uniqueness. The reflection of this expertise to the HMI system is about the interaction choreography, referring to every movement that a control requires for interaction – such as the touch pressure, pace, and smoothness of the movement. Digitalisation plays an active role in the realisation, usually in negative sense by breaking the visual flow of the interior because of the need to accommodate flat, black plastic displays. This situation can be identified as an opportunity considering the flexibility of the digital content a screen offers. Moreover, NEU interactive technologies such as see-through displays could facilitate the ability to become invisible when not in use and provide a digitally more flowing dashboard to the driver.

Materials communicate luxury through not only physical properties but also the meanings associated with them. The luxury sector uses the rare, generally natural and unique materials such as wood (unique by its patterns), leather (it is unique to an animal also, crafted by experts) and metals (precise and strong) providing the exclusivity. Besides their uniqueness and precise realisation details, the physical qualities such as the distinctive smell, softness, and warmth of leather could provide consistency in terms of smell and touch within the car and throughout the years. However, warmth is not always associated with positive experiences: the temperature of the elements should be aligned with the use of frequency and duration. For example, the warmth of leather provides a cosy experience on constantly-contacted elements such as the steering wheel, however the cold metal touch on controls that are not used in longer periods provide a freshness with clean connotations. The challenge in deciding on materials is maintaining consistency within the car and within the brand for providing tactual flow and brand attachment throughout the years.

Finally, the form, which is about the interior spatial organisation for providing a visual flow, as well as the details within the controls and elements, could support the feeling of being special for the user. The form of luxury car interiors used to depend on the heritage, which could easily be built through the consistency of materials and realisation details (i.e. textures, finishing) within the car and brand. However, today the main challenge for the form is the integration of the large screen (actually a large amount of potentially rapidly-changing information) and the small, generally plastic controls onto the flowing wooden dashboard or leather steering wheel.

These three principle themes are not in isolation, they have overlapping or connecting sub-themes affecting each other. The relationship in between these themes is visualised as a map summarising the links in between them. The map highlighted the overlapping constructs, such as the customisation trend which can be observed within every sector. The customisation theme is in relationship with nearly all themes directly and indirectly. For example, customisation based on driving context is also changing the ease of use and comfort during driving experience. Another effect of customisation is on the physical embodiment details. The customisation through materials, form and realisation could be followed by customisation in use with the new technologies. Such as the customisation of the controls even in terms of their forms could be possible with the NEU interactive technologies changing the entire form and realisation details of car interiors. Also, the information presentation in terms of content and layout could provide ease of use as well as change the interior organisation affecting both physical embodiment and human factors within the car.

Smartness can be seen as a supporting theme that could provide seamless customisation for comfort and ease of use. Smart technologies present opportunities for each theme however, directly linked with customisation providing the ability to sense and act accordingly to the products. Form, ease of use and customisation overlaps regarding the control UX which is also directly linked with the materials. The map of luxUX provides design considerations as well as directions and relationships to designers. The constructs presented on the map could either support or become starting points for design briefs in luxurious automotive sector.

- How can designers apply NEU (new, emerging, unusual) interactive technologies to car interiors intended to deliver luxurious interaction?

The findings of the interviews created a map of luxury UX and the review of NEU interactive technologies provided necessary inspiration as inputs for the concept design phase of the research. A set of three HMI concepts has been introduced to illustrate the reflection of NEU technologies onto car interiors, and as a source to show how the research findings can be used as the basis of new-generation HMI systems. These concepts provided solutions such as:

- *the invisible assistant concept*, offering a sense of control through an easy to use HMI system and comfort settings for creating a calm and relaxed driving experience. This concept is not reflected on the physical embodiment radically; however, it changes the driving experience through information, assistance and comfort settings.

- *my butler concept,* creating a smart HMI system that recognises the user and is attentive to contextual elements, thereby making suggestions and acting accordingly. The smartness of the system is based on the sense of progress and customisation for emphasizing competence of the driver. This concept assists the driver; however, the HMI sometimes becomes witty and stands out in presenting information and becoming involved in the decision-making process. This is for drivers to feel their competence and use their skills, but also to be open to suggestions and even sometimes argue with the HMI system.

- *the unique interior concept,* offering a radical solution of removing most of the physical controls and information through digitalisation. The unique interior supports the feeling of being special by creating an interior with flowing wooden, leather and metal surfaces without any interruption. It also offers a performance-focused environment by staying away from information bombardment to allow the driver to focus on feeling the performance of the car.

SRQ.2 - How can we devise the design appraisal process for luxurious automotive HMI systems and experiences?

The secondary aim of the research was to provide information for how to virtually prototype the experience of using NEU interactive technologies within an automotive HMI context. Alongside this was the requirement for more effective and feasible evaluation environments. The second sub-research question is also connected to the following two questions, for revealing the criteria for setting up simulation environments for appraising in-car HMI systems.

- What kind of simulation tools are more suitable and effective for appraising in-car interactions?

- What factors should be considered when designing a feasible evaluation environment for appraisals of luxurious automotive HMI?

These two questions were answered through a workshop organised in collaboration with the Virtual Engineering Centre. The workshop was built on the technology review that had been carried out in preparation and was designed to gather the expert opinion of simulation professionals on the creation of evaluation environments for NEU interactive technologies.

- What kind of simulation tools are more suitable and effective for appraising in-car interactions?

The criteria for the choice of simulation tools for appraising particular in-car interactions are based on a variety of factors. The initial criteria, which consists of three components as suitability (AR, MR, VR), availability (hardware and software), research & development (time & effort, cost, and impact), was established as directly linked to each other. The choice of the level of reality (AR, MR, VR) is in relation to the availability of the necessary equipment and expertise of the people and the facility. The level of required simulation precision is defined by:

· *mapping* (mapping visuals on a mobile or fixed element); such as in the example of flexible displays, mapping visuals on a mobile and flexible display might become challenging especially in mixed reality options. However, in VR environments mapping of visual content on a flexible display does not pose any particular challenges.

· *tracking* (tracking one or multiple elements) such as in the example of eye tracking, the tracking range could change the characteristics of the necessary equipment, such that head tracking for larger areas might be sufficient, whereas precise eye tracking is more likely needed for smaller areas.

· *resolution* (visuals on a small or large screen) is related to both the precision of the visuals as well as the tracking. The deformable displays were illustrated with two examples, one of which did not require precise tracking and visuals since it was based on the 2D action of the user. However, the other display technology involves deformation of images on the screen, based on the hand movement and gestures of the user. That process requires precise imagery mapping on the screen as well as precise tracking of fine hand or finger movements to be reflected in the imaging process.

The level of precision in relation to mapping, tracking, and resolution also affects the time, effort and costs associated with the simulation research and development process. For example, the simulation of flexible displays is relatively easy in a VR environment whereas in AR and MR environments it would create challenges in terms of available equipment, mapping process and R&D investment. Moreover, the contextual details (i.e. the scenario, role of the technology in interaction) is also effective for the suitability of the simulation tools. As a result, this research question is tied to the answers to the following research question.

- What factors should be considered when designing a feasible evaluation environment for appraisals of luxurious automotive HMI?

The criteria for creating the evaluation environment for appraisal of luxurious automotive HMI are related to the details of the usage scenario (in which the interactive technology is applied) as well as outside factors.

- The details of the usage scenario:

  · *The role of the technology (input, output, etc.)*

  · *The properties of the product (mobile, fixed, etc.).* This is a challenge particularly for visual technologies regarding the mapping of visuals on a mobile screen as well as multimodal scenarios. Tactile touch screens exemplify this situation with their ability to change the location of tactile elements based on the location of visual elements. In this case, the co-location of the visual and tactile sensations and mapping both onto a mobile device would become very challenging.

  · *Length of interaction* (immediate vs. long-term responses). As in the example of the use of biometrics, if it is just for identification the process becomes quite easy and achievable without additional sensors as the participant is already identified by the researchers. However, if the process is based on constant monitoring of biometric information the process requires additional equipment for monitoring and acting.

  · *Scenario details* (the expected input and output details, user ID, open scenario, etc.). The expected output for the same input may change, for example identifying a certain song through audio fingerprinting might bring changes in the visual organisation of the HMI screen which is achievable. On the other hand, it might affect the physical comfort arrangements which require further equipment and R&D process.

  · *Context of use* (daytime, night-time, alone, collaborative, etc.). There are also effective in terms of visuals based on the lighting conditions as well as a change in lighting conditions, as in the scenario of entering into a tunnel while driving. Also, the number of people interacting simultaneously is another factor to consider while designing evaluation environments. Generally, the simulation environments are set up for only one user. However, the context might require more than one person to be tracked, for example a front-seat passenger alongside the driver, which places technical demands on the tracking resolution and precision.

- Outside factors:

· *Range of available equipment.* Simulation tools are under continual development, with tools for simulation of visual elements having received most of the attention until now. This can be not only because of the dominance of visual-triggered interaction with automotive HMI, but also because visual technologies are generally rated as easier to be simulated. In contrast, the simulation of smell, with its complexity, chemical character and lack of available equipment, is rated as more costly and time consuming compared to deploying a source of authentic smell within the simulation area.

· *The experience level of participants.* The expertise of the participants reflected upon their evaluations of simulation feasibility, especially regarding R&D time, effort and cost. The prototyping of certain technologies out of their expertise might require longer time, effort and cost including the learning process and procurement of necessary equipment. Participants specialized in VR might overlook or underestimate other options; therefore, the consultation process for automotive HMI simulation should aim for breadth in expertise with varieties of technology.

8.3 Limitations of the Research

The pursuit of the above answers to the research questions required collaborations and input from partners, which came with challenges and limitations on the research. These are explained in this section. There were several limitations of the study stemming from the partnerships and the nature of the luxury automobile industry.

Firstly, the partnerships – which were new to all parties at the outset of the research - created several opportunities as well as challenges and limitations in terms of research design, planning and implementation. The initial plan for the research was to focus on developing simulation technologies for evaluation of luxurious driving contexts. However, over time constraints of the partnerships and planning problems required the research to change its focus onto a more fundamental investigation of factors influencing luxury car-driving experiences. Thus, the research program had to switch part way through from a digital/simulation study to a UX/HMI-design study. As a result, a considerable period of time was needed to expand the literature review and redefine the research goals and aims, based on the justification that the newly reviewed literature clearly revealed gaps and opportunities for an experience-oriented approach focusing on the definitions and descriptors of luxury driving experiences.

Secondly, the nature of the luxury sector requires discreetness in terms of data sharing and presentation. Even though a series of confidentiality agreements had been signed by the researcher, the access to in-house insights from Bentley Motors Ltd. was restricted and ineffective with regard to content and formal documentation. For this reason, the research principally relied on literature findings and field studies rather than industry input.

Thirdly, and quite surprisingly, the luxury sector users are relatively inaccessible even by the luxury companies. Most of the time these people are not willing to make time for research studies or share data because of their social status or fame. For this reason, it was not possible for the researcher to carry out interviews or generative studies with the 'true' luxury car customers. However, it is believed that this limitation is overcome by carrying out interviews with the people designing for luxury car customers, who are themselves close to the values of the customers and who have insights and inside information in the company. These people have a comprehensive knowledge and experience based on their exposure and involvement with specialist information gathered through marketing research. For this reason, it is argued that they represented the most feasible and practical participant set, being familiar not only with the demands and needs of luxury drivers, but also the trends and developments in the automotive industry (which luxury car owners and drivers may not be). Moreover, all the participants were devoted and willing to make time for the interviews, which in turn made them better candidates for interviewing about their experiences.

Finally, similar to many collaboration-based studies, this PhD faced several delays, required re-planning, and for calendars, timetables and paperwork to be adjusted throughout the conduct of the study. Partially this is because the PhD was wide-ranging in scope, with the candidate given responsibility to determine the precise research topic, rather than it being predefined at the outset as is typical with many engineering-based studies. However, the necessary tasks and setbacks were treated with a positive outlook: the multifaceted nature of the research nurtured the process and equipped the researcher with better planning skills and heightened awareness of strategies including back-up plans.

8.4 Recommended Future Research

This PhD has contributed to the knowledge on designing for luxurious experiences in an automotive context. It has set the foundations, dimensions, terminology and concepts for more detailed and focused follow-up studies on designing for, or evaluating, luxury in automotive HMI. The completed work can form a base study for follow-up studies that seek to understand in more depth, for example, the luxurious experience from a design perspective, the dynamics of car HMI systems, or the practical use of simulation tools for evaluating NEU interactive technologies.

The future of luxury is a hot topic. It is being discussed especially in the fashion industry where, as with the new generation of luxury cars, the definitions of luxury clothing are needing to change. The concept of luxury no longer refers to tangible attributes. It is about the sophistication behind a product, service or fashion element. Another facet of luxury is the unique 'experience' is a very wide sense, which can be achieved through the support of products and services on a system basis, such as climbing highest mountains, visiting remote areas, etc. Traditional luxury values are changing with the characteristics of the newer wealthy classes. The traditional luxury customer was once the aged people valuing heritage and tradition. Today, however, with the technology start-ups the luxury class is younger and technology-oriented. Besides, this class is generally more environmentally conscious, seeking hedonic satisfaction in more sustainable and caring ways. Thus, a fruitful direction for future research can be the consideration of new materials and novel experiences in a luxury context, but with the added dimension of supporting sustainability and treating ethical issues sensitively.

On the other hand, from a driving perspective, even though Bentley state that they offer "ultimate autonomous driving through chauffeur experience", it is an undeniable fact that autonomy will become more and more widespread in all transport sectors. These changes will challenge and force the luxury car industry to look for additional features to differentiate their in-car experiences from the masses of non-luxury vehicles. Autonomous driving and autonomous vehicles are currently being discussed in relation to design and experience as well as ethical and legal issues/responsibilities. There are already a number of autonomous driving concepts for luxury brands, such as 'Mercedes Benz F 015 – A Luxury in Motion' (Mercedes Benz, 2015) and 'Bentley - The Future of Luxury' concept (Golson, 2016). Therefore, the luxuriousness of in-car technology and HMI systems for autonomous cars will be discussed at length by researchers and designers in the coming years. This present research provides a head start for those detailed discussions.

Finally, digital simulation and evaluation technologies are popular and exciting because of their novelty. However, this area also requires a fresh point of view that takes the focus off discussions and research effort away from visual mimicry – especially in VR – towards serious technology and software development to achieve proper multimodal simulation of fine product details and fine user interactions. Also, the potentials of mixed reality options, especially in the evaluation of user-product interactions (not tied to the automotive sector), is another area that will benefit from concentrated research and development.

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APPENDIX A

PARTICIPANT INFORMATION FORM: FOR WORKSHOP ON NEU TECHNOLOGIES

"Evaluation of new/emerging interactive technologies for automotive industry according to the complexity and feasibility of implementation through simulation tools"

You are kindly invited to participate in the workshop "Evaluation of new/emerging interactive technologies according to the complexity and feasibility of implementation through simulation tools". The workshop will take place on March 9, 2017, Thursday 10.00-12.30 at STFC Daresbury Laboratory Virtual Engineering Centre Board Room. You have also received a document (technology_review.pdf) explaining around twenty new/emerging interactive technologies and if you agree to participate in the workshop you are expected to evaluate these technologies during the event. Please take time to read the following information and feel free to ask us if you would like more information.

Thank you for reading this.

What is the purpose of the study?

The study aims to get expert opinion on the challenges and potential of virtual reality (VR) / augmented reality (AR) to simulate a variety of new and emerging technologies for interacting with products. The 'product' in this particular case is automotive HMI (human-machine interfaces).

Why have I been invited to take part?

To evaluate the suitability to simulate the interaction technologies using VR/AR, we are looking for simulation professionals from the VEC to familiarise themselves with the interaction technologies (a document is sent) and to provide expert opinion in evaluating those technologies against certain criteria. It is planned to have 5 participants from different professions, such as visualisation, programming etc.

Do I have to take part?

No. Participation in this study is voluntary. If you do decide to take part, you are free to withdraw at any time, without giving a reason and without incurring a disadvantage.

What will happen if I take part?

If you agree to take part in the study, before attending the workshop you will need to review the document which explains and summarises fourteen new/emerging interaction technologies. You are expected to familiarise yourself with these technologies and be prepared to evaluate them according to certain criteria during the workshop. The workshop will take place at the VEC facilities and will last for two and a half hour.

Expenses and payments

There are no expenses or payments for this study.

Are there any risks in taking part?

There are no known physical or mental risks associated with taking part in this study.

Are there any benefits in taking part?

The benefits of attending this study are; i) familiarisation with new/emerging interaction technologies, which can be professionally useful, and ii) collaborative brainstorming with different professionals on how to simulate new/emerging interaction technologies.

What if I am unhappy or if there is a problem?

If you are unhappy at any point in the study, or if there is a problem, please tell the Research Student in attendance at the workshop, or let us know by contacting the Supervisor Dr. Owain Pedgley at the address or phone number below. If you remain unhappy or have a complaint which you feel you cannot come to us with then you should contact the Research Governance Officer (RGO) at the University, on 0151794 8290 or via email at ethics@liv.ac.uk . The RGO is in charge of making sure our research is done properly. When contacting the Research Governance Officer, please provide details of the name or description of the study ("Evaluation of new/emerging interactive technologies for automotive industry according to the complexity and feasibility of implementation through simulation tools") so that it can be identified. Please tell us the names of the researcher(s) involved (i.e., Supervisor: Dr. Owain Pedgley, Research Student: Sevcan Yardım Sener), and the details of the issue you would like to raise.

Will my participation be kept confidential?

Yes. All the information collected about you during the course of the research will be kept strictly confidential. All the information you provide will be identified only by a random 'participant number'. Therefore, all data that you provide will be anonymised.

Will my taking part be covered by an insurance scheme?

Participants taking part in any study that has been ethically approved by the University of Liverpool are covered by the University's insurance scheme.

What will happen to the results of the study?

All the information collected about you during the course of the research will be anonymised. No personal information will be disclosed to anyone. All the information recorded as video, audio and photographs will be kept on the University's secure network drive and will be accessible only by the Research Student and the Supervisor.

This study will be followed by other studies with different professionals. The anonymised results will be presented to the VEC and other parties, as part of the Research Student's PhD research programme.

We intend to publish the findings from this study and following studies in academic conferences and journals. When we do so, we are sometimes required to share the anonymised data set on public data repositories so that other researchers can scrutinise our data. It is important to clarify that all data offered to public data repositories or shared with other researchers will be anonymised, so it will not be possible to identify individual participants. All procedures for handling and storing of data will comply with the Data Protection Act 1998.

What will happen if I want to stop taking part?

You are under no obligation to take part in this study; it is completely your choice. If you do decide to take part, you are free to withdraw at any time without giving reason or explanation.

Data collected up until the period you withdraw may be used, but only if you are happy for this to be done. Otherwise you may request that your data be destroyed and no further use is made of them.

Who can I contact if I have further questions?

If you have any questions then please contact:

the Research Student:

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e-mail: sevcany@liverpool.ac.uk

telephone: 07935 785 611

and the Supervisor:

Dr. Owain Pedgley

e-mail: pedgley@liverpool.ac.uk

telephone: (0)151 794 4859

APPENDIX B

CONSENT FORM: FOR WORKSHOP ON NEU TECHNOLOGIES

"Evaluation of new/emerging interactive technologies for automotive industry according to the complexity and feasibility of implementation through simulation tools"

PARTICIPANT CONSENT FORM

Title of Research Project:	"Evaluation of new/emerging interactive technologies for automotive industry according to the complexity and feasibility of implementation through simulation tools"
Researcher(s):	Mrs. Sevcan YARDIM SENER, Dr. Owain PEDGLEY

		Please initial box
1.	I confirm that I have read and have understood the information sheet dated 9 March, 2017 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
2.	I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected. In addition, should I not wish to answer any particular question or questions, I am free to decline.	
3.	I understand that, under the Data Protection Act, I can at any time ask for access to the information I provide and I can also request the destruction of that information if I wish.	
4.	I understand that confidentiality and anonymity will be maintained and it will not be possible to identify me in any publications.	
5.	I agree for the data collected from me to be used in future research and understand that any such use of identifiable data would be reviewed and approved by a research ethics committee.	
6.	I understand and agree that my participation will be video recorded and I am aware of and consent to your use of these recordings to be analysed for following studies.	
7.	I understand that my responses will be kept strictly confidential. I give permission for members of the research team to have access to my	

anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research.

8. I understand and agree that once I submit my data it will become anonymised and I will therefore no longer be able to withdraw my data. ☐

9. I agree to take part in the above study. ☐

Participant Name	Date	Signature
Name of Person taking consent	Date	Signature
Researcher	Date	Signature

Supervisor:
Dr. Owain PEDGLEY
School of Engineering, University of Liverpool

Brownlow Hill, Liverpool, L69 3GH, UK
0151 794 5370
pedgley@liverpool.ac.uk

Student Researcher:
Sevcan YARDIM SENER
School of Engineering, University of Liverpool

Brownlow Hill, Liverpool, L69 3GH, UK
07935 785 611
sevcany@liverpool.ac.uk

APPENDIX C

PARTICIPANT INFORMATION FORM: FOR INTERVIEWS ON LUXURY DRIVING AND INTERACTION EXPERIENCES

UNIVERSITY OF LIVERPOOL

“Integration Problems and Opportunities within Car HMI”

You are kindly invited to participate in the interviews aiming to identify “Integration Problems and Opportunities within Car HMI”. The interviews will take place during August-October 2017, at your convenience. During the interviews, you will be asked to talk about your experiences with your car HMI (especially your experiences with navigation system) related with integration problems. The interviews ***will take place in your own car*** *(**parked at Bentley Car Park)** to stimulate your memories about your experiences. Please take your time to read the following information and feel free to ask us if you would like more information.*

Thank you for reading this.

What is the purpose of the study?

Navigation is an important part of the driving experience that requires drivers to collaborate with the HMI system during this experience. Moreover, during that collaboration, the system should be more active than the driver as the driver is focused on the driving activity but she/he also requires dynamic information provision during the navigation experience. The definition of navigation is also changing and becoming more complex. Navigation is not simply going from point A to point B, now it is offering options such as, following a faster, shorter route or going through point C etc. The focus is not only on the result (reaching to the point B) but it is on the journey itself and how to reach the end point of the journey.

Moreover, navigation experience is highly affected by context, which can be explained by four different factors: environmental factors (i.e. weather, road), social factors (i.e. other passengers, other vehicles), personal factors (i.e. driving experience, personality) and technical factors (i.e. usability, connectivity). It is important to provide an integrated system to drivers to maintain a flowing, luxurious experience when they are navigating. It is quite possible to find out integration problems related to technical factors for researchers but understanding the integration problems within different contexts requires detailed user research focusing on the driving scenarios. This study aims to find out driving scenarios focusing on navigation experience in which drivers are faced with integration problems and to identify the well or ill-designed HMI features.

Why have I been invited to take part?

The study focuses on the positive and negative experiences with car navigation systems in different contexts. We are looking for car drivers, who may own and drive high end/luxurious cars or who are familiar with a luxurious driving experience. The study is structured to stimulate the memories of the drivers. They will be asked to share their positive and negative navigation experiences about driving high end/luxury cars related with integration problems. It is planned to have around 30 participants who are willing to carry out these interviews in their cars and to share their experiences.

Do I have to take part?

No. Participation in this study is voluntary. If you do decide to take part, you are free to withdraw at any time, without giving a reason and without incurring a disadvantage.

What will happen if I take part?

If you agree to take part in the study, we will set up a timetable at your convenience and we will ask you to park your car at the Bentley car park, where the study will take place. You will meet with the researcher at the Bentley reception, where you will be introduced to the necessary forms and interview structure.

During the interviews, you will be sitting in your own car (*the car will remain static with the electrical system switched on, but at no time will you be asked to drive*) and the researcher will introduce a mood board created with several images on driving contexts and a graphic that is summarising your navigation experience task by task. You will then be asked to share your negative and problematic experiences related with integration problems about your car navigation system (built-in system, navigation device or mobile phone). The interviews are planned to take place in **your own car, parked at Bentley car park** and will last about 20 to 30 minutes. Whole process will be **recorded as video (emphasising moving image + audio) and still images (HQ for documentation purposes).**

Expenses and payments

There are no expenses or payments for this study.

Are there any risks in taking part?

There are no known physical or mental risks associated with taking part in this study beyond what may be experienced in a normal working day.

Are there any benefits in taking part?

There are no defined benefits, but hopefully you will enjoy sharing your driving experiences with us. Additionally, you may find out interesting insights into positive and negative product emotions and car HMI design.

What if I am unhappy or if there is a problem?

If you are unhappy at any point in the study, or if there is a problem, please tell the Research Student in attendance at the interview, or let us know by contacting the Supervisor Dr. Owain Pedgley at the address or phone number below. If you remain unhappy or have a complaint which you feel you cannot come to us with then you should contact the Research Governance Officer (RGO) at the University, on 0151794 8290 or via email at ethics@liv.ac.uk. The RGO is in charge of making sure our research is done properly. When contacting the Research Governance Officer, please provide details of the name or description of the study ("Integration Problems and Opportunities within Car HMI") so that it can be identified. Please tell the RGO, the names of the researcher(s) involved (i.e., Supervisor: Dr. Owain Pedgley, Research Student: Sevcan Yardım Sener), and the details of the issue you would like to raise.

Will my participation be kept confidential?

Yes. All the information collected about you during the course of the research will be kept strictly confidential. All the information you provide will be identified only by a random 'participant number'. Therefore, all data that you provide will be anonymised.

Will my taking part be covered by an insurance scheme?

Participants taking part in any study that has been ethically approved by the University of Liverpool are covered by the University's insurance scheme.

What will happen to the results of the study?

All the information collected about you during the course of the research will be anonymised. No personal information will be disclosed to anyone. All the information recorded as video (emphasising moving image + audio) and still images (HQ for documentation purposes) will be kept on the University's secure network drive and will be accessible only by the Research Student and the Supervisor.

This study will be followed by other studies that will lead to design solutions for new car HMI.

We intend to publish the findings from this study and following studies in academic conferences and journals. When we do so, we are sometimes required to share the anonymised data set on public data repositories so that other researchers can scrutinise our data. It is important to clarify that all data offered to public data repositories or shared with other researchers will be anonymised, so it will not be possible to identify individual participants. All procedures for handling and storing of data will comply with the Data Protection Act 1998.

What will happen if I want to stop taking part?

You are under no obligation to take part in this study; it is completely your choice. If you do decide to take part, you are free to withdraw at any time without giving reason or explanation.

Data collected up until the period you withdraw may be used, but only if you are happy for this to be done. Otherwise, you may request that your data be destroyed and no further use is made of them.

Who can I contact if I have further questions?

If you have any questions then please contact:

the Research Student:

Mrs. Sevcan YARDIM SENER

e-mail: sevcany@liverpool.ac.uk

telephone: 07935 785 611

and the Supervisor:

Dr. Owain Pedgley

e-mail: pedgley@liverpool.ac.uk

telephone: (0)151 794 4859

APPENDIX D

CONSENT FORM: FOR INTERVIEWS ON LUXURY DRIVING AND INTERACTION EXPERIENCES

"Integration Problems and Opportunities within Car HMI"

PARTICIPANT CONSENT FORM

Title of Research Project: "Identifying integration problems and opportunities within car HMI"

Researcher(s): Mrs. Sevcan YARDIM SENER, Dr. Owain PEDGLEY

Please initial box

10. I confirm that I have read and have understood the information sheet dated, July 2017 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

11. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected. In addition, should I not wish to answer any particular question or questions, I am free to decline. ☐

12. I understand that, under the Data Protection Act, I can at any time ask for access to the information I provide and I can also request the destruction of that information if I wish. ☐

13. I understand that confidentiality and anonymity will be maintained and it will not be possible to identify me in any publications. ☐

14. I agree for the data collected from me to be used in future research and understand that any such use of identifiable data would be reviewed and approved by a research ethics committee. ☐

15. I understand and agree that my participation will be recorded as video (emphasising moving image + audio) and still images (HQ for documentation purposes) and I am aware of and consent to your use of these recordings for analysis. ☐

16. I understand that my responses will be kept strictly confidential. I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the ☐

research materials, and I will not be identified or identifiable in the report or reports that result from the research.

17. I understand and agree that once I submit my data it will become anonymised and I will therefore no longer be able to withdraw my data.

18. I agree to take part in the above study.

Participant Name	Date	Signature
Name of Person taking consent	Date	Signature
Researcher	Date	Signature

Supervisor:
Dr. Owain PEDGLEY
School of Engineering, University of Liverpool

Brownlow Hill, Liverpool, L69 3GH, UK
0151 794 5370
pedgley@liverpool.ac.uk

Student Researcher:
Sevcan YARDIM SENER
School of Engineering, University of Liverpool

Brownlow Hill, Liverpool, L69 3GH, UK
07935 785 611
sevcany@liverpool.ac.uk

APPENDIX E

TECHNOLOGY CARDS FOR CARD-SORTING ACTIVITY

APPENDIX F

CURRICULUM VITAE

Sevcan YARDIM ŞENER, Lecturer at Industrial Design Department, TOBB University of Economics and Technology, Ankara/TURKEY, Phone +905067119098, e-mail: sevcanyardim@gmail.com

EDUCATION

PhD. in Industrial Design – 2019, University of Liverpool
Thesis Title: Design For Luxury Automotive HMI Systems and Driver Experiences
Supervisors: Dr. Mark WHITE, Prof. Dr. Owain PEDGLEY
Master of Arts –2012, Hacettepe University
Department of Interior Architecture& Environmental Design (3.79/4.00)
Thesis Title: A Research on the Construction of Future Perception by the Design of the Space and Objects in the Science Fiction Films
Supervisor: Mesut CELIK
Bachelor of Industrial Design – 2007, Middle East Technical University
Department of Industrial Design (3.05/4.00)

PUBLISHED WORKS

Yardım Sener, S., & Pedgley, O. (2019). To simulate or not to simulate? Challenges in digitally prototyping HMI interactive technologies. Proceedings of ProDPM 2019 Progress in Digital and Physical Manufacturing, (pp. 82-88). Leiria.
Yardım Sener, S., Sen, G., Pedgley, O., Sener , B., & Murray, G. (2016).Y Product Experience and Luxury Values. 10th International Conference on Design & Emotion (pp. 107-113). Amsterdam
Yardım, S. (2014). Generating Positive Emotions During Driving. The Product Qualities of a Car Affect Emotional Conditions. The colors of care : 9th International Conference on Design & Emotion (pp. 500-511). Bogota: Universidad de los Andes.

EMPLOYMENT

Lecturer – April 2019 – cont.
TOBB University of Economics and Technology
Research Associate - November 2017- June 2018
University of Liverpool - Dilemmas of Happiness Project (Knowledge Exchange and Impact Award) Project Manager: Dr. Deger OZKARAMANLI
Teaching Assistant - 2015-2017
University of Liverpool - Industrial Design Division
Assisting Modules;
- Product Form and Materials

- Product Design Group Project

Research & Teaching Assistant - 2010-2014

TOBB University of Economics and Technology - Department of Industrial Design
Assisting Modules;
- Industrial Design Studio I-II (Teaching first steps of industrial design)
- Graduation Project (Organising calendar and management of prototype processes)
- Model Making (responsible for workshop and equipments)
- Erasmus and Web Coordinator

Research & Teaching Assistant - 2009-2010

Halic University - Department of Industrial Design
Assisting Modules;
- Industrial Design Project II-III (Teaching first steps of industrial design)
- Computer Aided Design VI (3D modeling with RhinoCeros)
- Model Prototype Production III-IV (responsible for workshop and equipments)

Freelance Experience

Yakan Lighting Company 2007–2008

In accordance with the production method of the Yakan Lighting Co., I have designed frames over a lamp in the shape of globe and several outdoor lighting elements. These designs are in production and registered by Turkish Patent Institute (TPE)

Karademir Furniture Company 2007–2008

Considering the traditional lifestyle of the local user group I have designed furniture alternatives

Arlight Lighting Company 2007–2008

"Bamboo" outdoor lighting element designed for offering users various heights and arrangements (Registered by TPE) published in several design blogs and newspapers (http://www.core77.com/posts/9054/bamboo-light-by-sevcan-yardim-9054)

ADMINISTRATION

During several years of experience as a research assistant at TOBB ETU I have hosted several events as a part of organising committee with the design of graphic elements, organising the timeline and communicating.
2014 ETAK - Academic Council of Industrial Design Departments of Turkey
2014 "Game Design" Workshop - IMMIB (Istanbul Minerals and Metals Exporters' Association)
Studio HDD Hakan Diniz
2012 "Design for All" Workshop - IMMIB (Istanbul Minerals and Metals Exporters' Association)
Prof. Lena Lorentzen
2012 Days of Oris - International Architect Congress
2011 Theory of Visual Culture Workshop - Assoc. Prof. Dr. Kevin Tavin

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AWARDS

EPSRC Doctoral Training Grant: IDS Studentship (March 2015 - March 2018) Full-time PhD Studentship in Industrial Design - University of Liverpool (Maintenance & Tuition Fees)

Design Competitions

Red Dot Design Awards 2013

Daisy (bedside alarm clock) - Shortlisted

IMMIB (Istanbul Minerals and Metals Exporters' Association) - Industrial Design Competitions 2008

Bubble (washbasin and bathtub stopper) - First Runner-up

Dokun-Aç (electric key switch) - Mention

Central Anatolian Exporters Union(OAIB) National Furniture Design Competition 2008

Roll-up (bookshelf) – Finalist

COMPUTER SKILLS

Advanced knowledge on Bitmap and vector graphics editing - Adobe Illustrator, Photoshop

Advanced knowledge on 3D modeling and rendering - RhinoCeros, Vray and working knowledge on 3Ds Max

Working knowledge on Augmented Reality applications - Metaio Creator&Junaio Browser, Augment and on Arduino Software and Arduino Uno

Expert knowledge on Microsoft Office

LANGUAGE SKILLS

Mother tongue Turkish

Fluency in English (IELTS Overall Score 7.5)

Beginner Spanish

HOBBIES

Photography

Theatre (MCD Youth Club Theatre Team)

Cinema & Film Analysis

Singing (University of Liverpool Pop Choir)