Co-designing with Drivers: A Human-Centred Approach towards the Implementation of Real-Time Contextual Interviewing

A thesis submitted for the degree of Doctor of Philosophy

By

Daniel de la Flor Aceituno

Brunel Design School, CEDPS, Brunel University London

Abstract

The automotive industry is facing an era of rapid evolution. This evolution is mostly driven by the development of sophisticated electronics and algorithms, which are partially affecting the drivers' behaviour inside the automobile, and gradually changing their customer experience. However, the process followed by carmakers to design new models has remained similar for decades, leading to inefficiencies in some of the current automotive design methodologies. To address those inefficiencies, there is an increasing tendency to collaborate with users while they are driving. This research took the view that automotive designers can conduct customer interviews while drivers are inside automobiles real-time, in a real-life context for the analysis and improvement of customer experience.

In order to explore the applicability of real-time contextual interviewing inside automobiles, four studies were conducted. Firstly, two simulator studies aimed to define some minimum requirements in terms of communication hardware and communication methods for real-time remote collaboration between automotive designers and automobile drivers. Subsequently, two more studies were conducted to explore possible benefits of such collaboration towards the collection of ethnographic data and improvement ideas and to explore its possible consequences towards the driver's emotions. The results of these studies suggested that real-time contextual interviewing can be effectively implemented inside automobiles to collect greater amounts of information in terms of quantity, variety and creative contents.

This research leads to an increased understanding of the methods which can be used to collaborate with customers in the automotive context. Suggestions collected through contextual interviewing provided opportunities to develop new models based on real-time customer feedback and experience economy. Thus, the practices of this research can be incorporated into future research methodologies to co-create a shared understanding of customer experience among designers and automobile drivers and to facilitate idea generation for the development of product ecosystems.

First Supervisor: Prof Joseph Giacomin, Human Centred Design Institute

Brunel University, Kingston Lane, Uxbridge UB8 3PH

Second Supervisor: Dr Alessio Malizia, School of Creative Arts

University of Hertfodshire, College Lane, Herts AL10 9AB

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Glossary

CAD	Computer Aid Design
CAN	Controller Area Network
CAT	Consensual Assessment Technique
CMC	Computer-Mediated Communication
CSCW	Computer Supported Cooperative Work
ECG	Electrocardiogram
FEA	Facial Expression Analysis
GSR	Galvanic Skin Response
HCD	Human-Centred Design
HCI	Human-Computer Interaction
IVNS	In-Vehicle Navigation Systems
LTM	Long-Term Memory
R&D	Research and Development
STM	Short-Term Memory
UX	User Experience
VPN	Virtual Private Network

1. Introduction

The automotive industry is currently facing a period of rapid evolution. It has been recently argued that *Connectivity* is the key factor contributing to the changes in the working practices and daily lives in modern society (Ibañez-Guzmán, et al., 2012). The development of sophisticated electronics and algorithms leads to the inclusion of new capabilities such as partly autonomous features (i.e. lane-keeping systems, self-parking systems), fully autonomous self-driving software or protocols to connect automobiles. Thus, the automobile is increasingly automating traditionally manual-driving tasks and in turn enhancing the range of activities that drivers can perform in and outside the automobiles (Smith, Vardhan, and Cherniavsky, 2017). All these upgrades require the integration of sensors, artificial intelligence, and cameras among many other devices, which are producing a vast amount of data. Indeed, Governments and institutions such as the European Commission are proposing novel policies to regulate the implementation of these technologies (European Parliament, 2019). For instance, the regulation (EC) No 1071/2009 regarding the occupancy of road transport operators was recently amended by the European Parliament in order to include their position towards the use of vehicles hired without drivers for the carriage of goods by road. In those amendments, it was recognised that driverless motor vehicles may often be safer and less polluting than motor vehicles operated by human drivers and therefore, these should be considered differently in terms of taxes (European Parliament, 2019).

This growing complexity is also affecting the attitudes that drivers have and the behaviours they exhibit towards other automobile drivers and towards the vehicle itself, offering the opportunity to explore new design approaches based on a wider range of data (Smith, Vardhan, and Cherniavsky, 2017; Manyika, et al., 2013). Among the innovative projects currently under development, there is an increasing tendency to collect user experience information (Bijl-Brouwer and Dorst, 2017). At this moment, automotive designers tend to focus on opinion questionnaires, online surveys, telephone interviews and trend analysis (Audi, 2017; Seat, 2017). However, research which has been performed regarding the impact of autonomous vehicles on policy and society recommended further investigation in ethnography inside vehicles (Milakis, Arem, and Wee, 2017). Ethnography is a research approach which focuses on the behaviour of the population in real-life contexts (Lazar, Feng, and Hochheiser, 2017). This recommendation suggests that automotive designers currently operate mostly with information consciously provided by customers, not fully considering how these customers use the vehicles in real-life contexts.

On the other hand, the use of online surveys, telephone interviews and trend analysis has been argued to present limitations caused by factors such as the decaying memory strength or the capacity to recall emotions equally, ultimately restricting the applicability of the results of the studies to the experimental conditions (Giuliano, Germak, and Giacomin, 2017; Ritchie et al., 2009). Thus, the limitations in some of these research practices in combination with the rapid evolution of automobiles' capabilities and the changes in the users' lifestyle lead to the need to adapt the current research and design methods employed by the carmakers to the Connectivity-based Era the world is technologically facing.

In order to explore how customers operate their products, companies in other sectors such as aerospace, defence or rail included their customers in the design stage of the products (Souri, Gao, and Simmonds, 2019; Evans, et al., 2015; Meschtscherjakov et al., 2011). To that end, research methods such as questionnaires, diaries, activity monitoring or contextual inquiry have been frequently implemented. Thus, these companies designed their products based on a shared understanding of how their products are used in real-life contexts (Rosenzweig, 2015; Olsson and Jansson, 2005).

In the automotive industry, researchers are currently exploring the opportunity of connecting designers with drivers while they are driving for real-time remote collaboration (Flor et al., 2019; Tasoudis and Perry, 2018; Martelaro and Ju, 2017; Gkatzidou, Giacomin, and Skrypchuk, 2016). Those researchers advocated for the use of contextual inquiry in order to provide professionals working in research and development with both customer feedback and creative ideas for the improvement of automobiles. Contextual inquiry is a research method which relies on the collection of data in the context where customers use a given product, to explore which aspects of the product support or interfere with its 'optimal' use. The collection of such data is frequently conducted via semi-structured interviews (Rosenzweig, 2015).

The research which is described in this thesis investigated several key elements involved in the implementation of such customer interviews between automobile drivers and designers, as well as the effect that these elements may have on the outcomes of those interviews.

1.1 Historical Evolution of Automotive Design

Since the invention of the first automobile in the late 1700s, the automotive manufacturing industry has evolved dramatically. From steam-powered automobiles to autonomous vehicles, uncountable changes have been implemented in the automobiles, and in turn, in all the processes required to bring them to the market. Most of these changes have been triggered by changes in the lifestyle and culture, but there is a factor which has been present along the whole automotive history since the automobiles became accessible to the average driver: the desire to create a semantic frame for the speed (Jaafarnia and Bass, 2011).

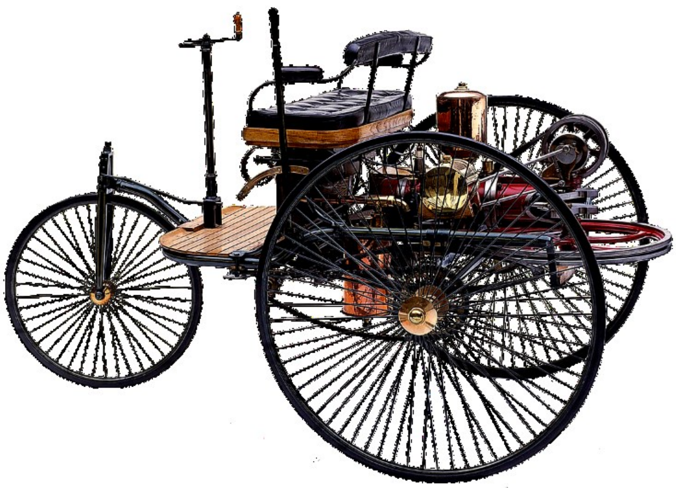


FIGURE 1: THE FIRST AUTOMOBILE PATENT BY KARL BENZ IN 1885 (EMSLICHTER, 2017)

In the beginning, the priority of the inventors was the function rather than the form of the vehicles, which looked basically the same. Subsequently, new concerns such as interior design, safety or aesthetics emerged and were gradually included in the design stage. In order to create some perspective about the current situation of automotive design, the first analysis of its historical evolution is presented in the next lines according to the structure proposed by Jaafarnia and Bass (2011). These researchers established seven eras to classify the evolution of the automotive design according to the cultural influences and technological innovations involved in the creation of automobiles. The mentioned eras presented in chronological order are the invention era (1885-1896), innovation era (1896-1908), manufacturing era (1908-1915), capsule era (1920-1930), classic era (1930-1940), integration era (1947-1968), modern era (1968-2008), and finally the second innovation era (2008-present day).

- **Invention era (1885-1896):** With the development of the Benz automobile patent (Figure 1), this era lasted for ten years until the introduction of Henry Ford's first automobile. The main focus of the creators relayed on the functionality of the machine, aiming to develop a first horseless carriage capable of human transport and capable of running entirely on its own power. These vehicles were powered by gas engines and included elements taken from the bicycles such as wire wheels or the structure of the carriage.

- **Innovation era (1896-1908)**: Part of society started finding a strange eccentricity in the fact that a carriage could move without a horse, which led automobile designers to agree that that carriage's form was not the most appropriate shape for the vehicles of the future and subsequently changed their core structure aiming to gain customers. In addition, new automobiles began to reflect other cultural changes such as the evolution from the old familiar to the fast-paced lifestyle, which could be noticed through their quick association to freedom and speed by their customers (Tumminelli, 2003).

- **Manufacturing era (1908-1915)**: In 1908 Ford Motor Company implemented production techniques which reduced significantly the production costs and ultimately the price of the final products. This fact led to the automobile customer profile being extended from hobbyists and enthusiasts who could easily afford an automobile to the ordinary man, implying a massive increase on the number of automobile owners and in turn a significant expansion of the automotive industry.

- **Capsule era (1920-1930)**: Due to the efforts of teams such as General Motors' automotive design grew into a separate discipline from the late 1920s onwards

(Sparke, 2002). During this era automotive designers started using the space within the cabin to modify the value and the semantic meaning of the automobile. To be specific, professionals of the industry discovered that changing the distribution of the automobile interior affects the emotional expression of that area for the driver (Jaafarnia and Bass, 2011).

- **Classic era (1930-1940)**: This era began with the Great Depression in 1930 and lasted for around ten years, shortly before World War II. Research in aerodynamics followed by numerous victories in motor-racing confirmed that long and slight shapes provide better performance than vertically modelled proportions. Thus, designers started creating vehicles inspired by aeroplanes and trains due to their implicit relationship with the speed. This led the automobiles of this period to leave behind the previous rectangular industrial shapes.

- **Integration era (1949-1968):** The automotive industry recovered its development pace in 1947, when the American carmakers General Motors, Oldsmobile and Cadillac incorporated the modern one-piece auto bodies to their production chain. During this era the designers focused on the improvement of consumer safety. Meanwhile, the marketing professionals prioritised the performance and muscle cars to increase sales. Subsequently, in the late 1950s, developing countries entered the automobile race.

- **Modern era (1968-2008)**: This era is characterised by the interest of the designers in the functionality of the automobile and the customer's emotional reactions to it. Thus, organic forms became the main source of inspiration for these professionals, replacing shapes from planes, trains or missiles. With the evolution of the society, three new types of an automobile were born and have secured a space in the market which lasts to the present day: the minivan, the hatchback, and the sports utility vehicle. In addition, the technology has grown to provide professionals with new tools such as the augmented reality or virtual modelling software, which can help to visualise and create the vehicles of the future.

- **Second innovation era (2008-present day):** Over the past decade, automotive companies have invested a significant amount of resources to the development of disruptive technologies such as fully electric automobiles or self-driving vehicles. This development is gradually changing the objectives of R&D teams from the improvement of the classic automobile mechanical and electrical features to the development of innovative AI solutions and user experiences (Manyika, et al., 2013).

To conclude with this summary about the evolution of automotive design, it is worth noting that literature about the discipline usually focuses on either the history of the automobile (Sparke, 2002), the design of aesthetics (Tumminelli, 2003) or the engineering issues related to the development of a new model (Reif and Dietsche, 2014) rather than the evolution of the automotive design process itself. This can be interpreted as an implicit assumption that the process itself has not evolved significantly since the Ford Motor Company introduced production techniques in 1908.

1.2 The Current Automotive Design Process

Motor manufacturers typically include a group of departments specialized in different fields which collaborate to define the goals of the new models according to the market needs, to design later their proposal of a model to satisfy these needs and finally, to develop a prototype for the new vehicle. This collaboration-based approach for product development also has been used in other industries such as aerospace or defence (Souri, Gao, and Simmonds, 2019; Hicks et al., 2002). The complete process for the development of a new automobile model typically lasts for 3-4 years and it involves a typical sequence of events (Figure 2). This generalised development process is the result of combining several literature sources in regards to the automotive design, engineering design and creative design from the perspective of cognitive psychology (Bryant, 2015; Howard, Culley, and Dekoninck, 2008).

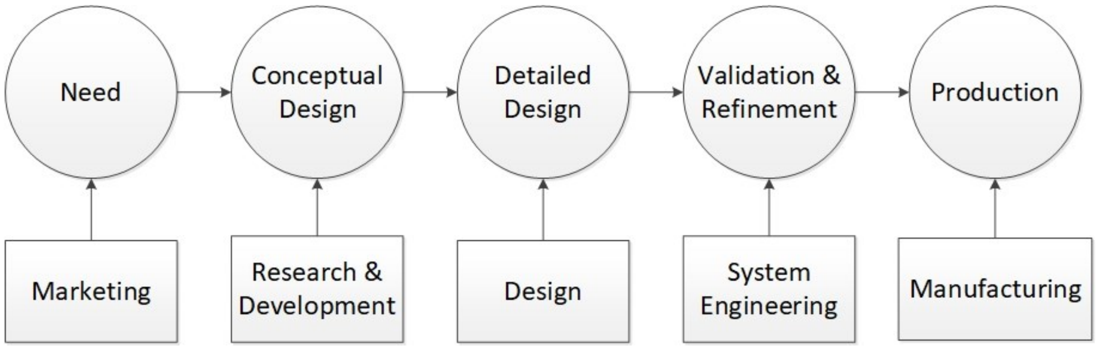


FIGURE 2 GENERALISED AUTOMOTIVE DEVELOPMENT PROCESS (BRYANT, 2015)

According to the generalised automotive development process proposed by Bryant (2015), five independent organisational units need to collaborate through five different stages to produce the prototype of a new automobile. These organisational units are marketing (leading the search for customer's needs), research and development (leading the conceptual design process), design (leading the detailed design stage), system engineering (leading the validation and refinement process), and manufacturing (leading the production activities). Even though the work scheme of the generalised automotive development process is sequential (Figure 2), the units tend to work simultaneously (Design Museum, 2013). The designers usually work on the "Conceptual Design", "Detailed Design" and "Validation & Refinement" stages, where they approach concurrently four main topics: the exterior of the automobile, the interior of the automobile, colour & trim, and finally graphic design.

Automotive designers who work on the exterior and interior design of the vehicle develop concepts according to the consumer trend and lifestyle research, expressing and visualising the ideas through detailed sketches (Tovey, Porter, and Newman, 2003). Simultaneously, a separate team of automotive designers performs market research in fashion in order to create a palette of colours for the model and selects the optimum materials for the trim (Hyundai, 2016) and graphic designers start working on the icons and symbols to be stamped at the on-board equipment. Once the envisioned design has been agreed, a 1:1 full-scale drawing is created by the designers aiming to match the actual proportions for the vehicle and proceed to the digital modelling stage. When the exact dimensions of the vehicle are agreed by the designers involved, the sketches previously made are rendered in 3D digital structure with the aid of computers, which allows virtually analysing the structure in terms of aerodynamics. To conclude the design process and after implementing any required modifications detected during the virtual tests, a 1:1 full-scale clay model is produced either handmade or with the use of a robot and Computer Aid Design software (also referred to as CAD) in order to reach a last subjective assessment among designers before starting the production stage.

On the other hand, recent research described the past three decades as a period of major changes in the methodologies used to design, the people in charge of the design process and the goals of the process itself (Sanders and Stappers, 2014). However, the strategies employed throughout the design process in these industries have remained stable over the period despite the changes in the supporting technology (i.e. 3D digital modelling, CAD, etc.). This links back to the assumption that the process itself has not evolved significantly in the since the Ford Motor Company introduced production techniques as described in the previous section.

Regarding the methodologies employed to explore customer's desires, as part of marketing studies, carmakers currently rely on opinion questionnaires, online surveys and stakeholder-interviews as SEAT company reported in their commercial materials (Figure 3). Those marketing studies are frequently conducted by designers working in the organizational units "Marketing" and "Research and Development", and they usually aim to identify region-specific customer requirements and expectations, especially towards the development of innovative technologies (Porsche, 2017; Volkswagen, 2017). More recently, it was increased the implementation of ethnographic research methods inside automobiles (Weber et al., 2018; Cha et al., 2015; Ramm et al., 2014). Those research methods mostly focus on interviews and observation during activity routine and they are typically conducted by professionals in "R&D" and "Design" in order to explore customers' desires based on data collected on-site.

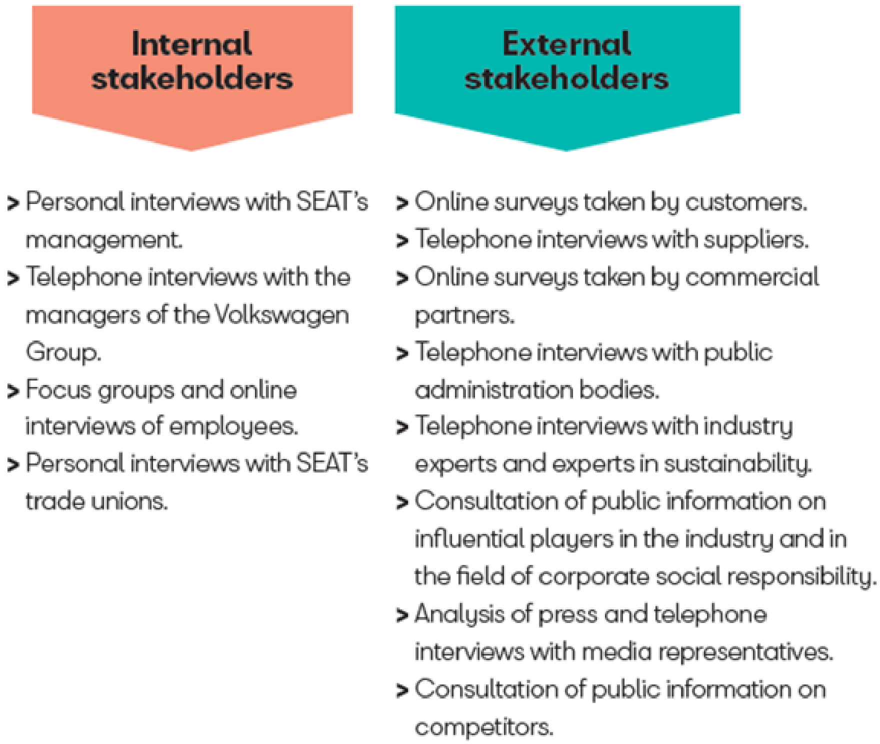


FIGURE 3: CONSULTANCY METHODS USED BY SEAT BASED ON THE ORIGINS OF THE STAKEHOLDERS (SEAT, 2017)

On the other hand, alternative methods such as data-driven design, social media-based co-creation and trend analysis based on online data have become increasingly popular (Cocca, et al., 2018; Hanelt et al., 2015). These are data collection methods which are implemented online and which are frequently used as decision support for designers when they are developing new models (Alkahtani, Choudhary, and Harding, 2019; Audi, 2017). All these methodologies are typically conducted during the first three stages of the generalised automotive design process (Figure 2) and also they are frequently implemented by professionals working in the departments of Marketing, R&D and Design.

1.3 Automotive Research Areas

As described in the previous section, the design of a new model for a vehicle typically takes between 3 and 4 years of work and the collaboration between professionals specialized in different disciplines. Among these groups of specialists, a reduced group composed mostly of the exterior, interior, and colour & trim designers perform market research which often takes several months and which makes use of surveys and interviews. These surveys and interviews are frequently tailored to address specific areas (Tullis and Albert, 2013). According to the literature, there is a number of traditional ergonomic areas frequently focused by automotive designers when designing new automobile models (Bhise, 2012). In this context, ergonomics refers to optimising the well-being of drivers and passengers and the overall performance of the automobile. On the other hand, the growth of sophisticated electronics and algorithms is partially affecting the behaviour of automobile users (Smith, Vardhan, and Cherniavsky, 2017). Thus, some automotive designers are currently conducting research in areas which were only partially considered in the automotive industry before (Peters, 2013; Tullis and Albert, 2013; Bhise, 2012). Excluding the highly specialist field of crash safety, typical topics which automotive designers take decisions on, and interact with the public to discuss, were summarised and listed (Table 1).

Areas Traditionally Addressed	Areas Increasingly Popular
• Engineering Anthropometry and Biomechanics • Occupant Packaging • Driver Information Acquisition and Processing • Controls, Displays and Interior Layouts • Field of View from Automotive Vehicles • Automotive Lighting • Entry and Exit from Automotive Vehicles • Automotive Exterior Interfaces • NVH (noise, vibration and harshness) • Vehicle Dynamics and Handling • Postural Comfort	• User Populations • Contextual Constraints • User Psychology • User Emotions • User Behaviour • Product Quality • Brand Consistency • Customer Satisfaction

TABLE 1: AREAS TRADITIONALLY AND RECENTLY EXPLORED BY DESIGNERS DURING THE AUTOMOTIVE DESIGN PROCESS

The research areas which are becoming increasingly popular among automotive designers are closely linked to the measurement of user experience within the automobile (Table 1). These research areas will be referred to as UX onwards. According to the literature, some of the research methods most frequently used to collect personal accounts of experience are the interviews, questionnaires and surveys (Martin and Hanington, 2012). However, the implementation of these methods frequently require interaction with respondents while they are out of the automobile, which causes their answers to be based on their long term memory and this may present some limitations (Ebbinghaus, 2011).

1.4 Limitations and Opportunities

As seen in the previous sections, automotive designers typically conduct market research in order to collect ideas for the development of new automobiles. These ideas are frequently collected through the use of surveys and interviews, which frequently cover a limited number of areas (Bhise, 2012). These methods are typically implemented on-line or via telephone call and literature suggested these research methods to present some limitations to collect realistic data (Giuliano, Germak, and Giacomin, 2017; Radvansky, Krawietz, and Tamplin, 2011; Radvansky, Tamplin, and Krawietz, 2010; Walker and Skowronski, 2009).

Previous literature suggested that the use of long-term memory to cluster opinion sometimes implies a lack of reliability (Ebbinghaus, 2011, Baddeley, 1997). To be specific, it is widely accepted (Melton, 1963; Murdock, 1962; Peterson and Peterson, 1959) that after 9 seconds, the percentage of verbal information which is typically recalled is lower than 40%, which suggests that people rapidly forget the wording of their own thoughts after such amount of time (Figure 4).

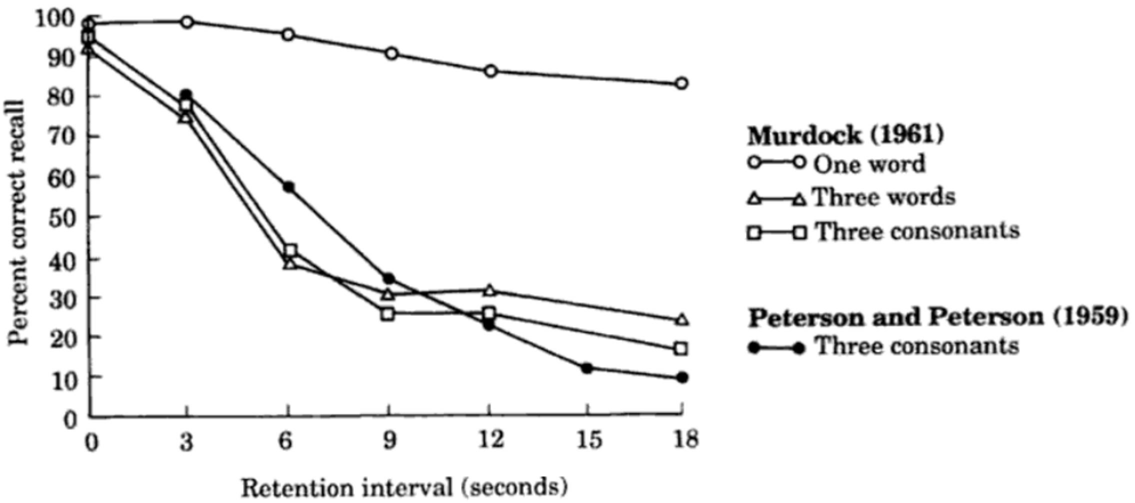


FIGURE 4: PERCENTAGES OF CORRECT RECALL AFTER A RETENTION INTERVAL (MELTON, 1963)

Additionally, the memories or thoughts created by an experienced event can be altered by other elements on top of the mere decline of the human memory. A large range of cognitive biases associated with any given experimental methodology will affect the reliability of the information which is reported (Benson, 2016). One clear example of cognitive bias affecting memory is the effect of fading on the experienced emotions (Walker and Skowronski, 2009).

It is widely accepted that memories containing negative emotions tend to fade quicker than memories containing positive emotions (Yuille et al., 1994; Goodman, et al., 1992). Further to this, the mere act of leaving the interior of the automobile can be argued to affect the accuracy of the memories due to the location updating effect (Radvansky, Tamplin, and Krawietz, 2010). Recent literature argued that moving between two spaces through a doorway to correlate with a decline in memory (Pettijohn and Radvansky, 2018; Radvansky, Krawietz, and Tamplin, 2011). Thus, the application of surveys, questionnaires and interviews on drivers while they are out of the automobile may provide different results to those potentially collected if these methods were applied in context.

On the other hand, other cognitive biases such as priming (Hauptmann and Karni, 2002) can potentially help stimulate the access to long-term memory if questions are asked while the person is staying inside the automobile. Priming investigates whether the exposure to stimuli affects the responses to future stimuli (Kahneman, 2011). Applied to the automobile, this effect can take place when drivers are asked questions about the automobile while they are actually using it, ultimately reducing their time to response (Weingarten, et al., 2016). On top of that, the automotive context is closely linked to the affective state of the drivers (Weber, 2017). The affective state of an individual has been defined as the result of the combination between emotions, mood and feelings (Jeon, 2015). Researchers advocated that positive affect enhances creative thinking (Kaufmann, 2003; Isen, 2001), whereas negative affect enhances analytic thinking (Jallais, et al., 2014). Thus, it has been recently argued that interviewing drivers while they are operating an automobile can help designers to grasp ideas for the development of new automobiles (Gkatzidou, Giacomin, and Skrypchuk, 2016).

In summary, automotive designers frequently use opinion questionnaires, surveys and telephone interviews to conduct market research for the development of new automobiles based on customer feedback and trend analysis. The respondents to those research methods are frequently affected by a range of cognitive processes, and these processes sometimes affect the outcomes of the market research. Some limitations of these research methods can be reduced through its implementation while customers are operating automobiles. The following sections introduce previous research in which designers collaborated with customers for the development of new products or services and discuss the possibility of implementing such collaboration in the automotive context.

1.5 Real-Time Collaboration with Drivers

As described in the previous sections, the development of sophisticated electronics and algorithms, the partially unaltered automotive design process and the limitations which some of the research methods implemented in the design process have led researchers to question whether automotive designers are fully considering how drivers use automobiles in real-life contexts when they are designing new models (Milakis, Arem, and Wee, 2017; Giuliano, Germak, and Giacomin, 2017). In order to improve the situation, some researchers in Manufacturing Engineering and Human-Centred Design shifted their attention towards collaborating with customers, which led to an increasing tendency to engage them in the design process (Flor et al., 2019; Defeo, Harding, and Wood, 2016; Ramm et al., 2015).

Previous research discussed the evolutionary benefits of collaborating with customers in the design process (also referred as co-designing) and some large companies started investing resources in improving their relationships with customers, suggesting that such an approach can help to develop new products or services (Sanders and Stappers, 2014; Leminen, Westerlund, and Nyström, 2012; Westerlund and Leminen, 2011). To be specific, industries such as fashion (e.g. Threadless) or photography (e.g. iStockPhoto) explored the option of collaborating with customers at the design stages through the use of crowdsourcing or design-driven labs, resulting in the commercialisation of new products (Brabham, 2013; Leminen, Westerlund, and Nystrom, 2012; Estellés-Arolas and González-Ladrón-de-Guevara, 2012).

In transportation, some examples of companies which collaborated with their customers include BAE Systems, SCANIA, Boeing or Bombardier (Agarwal, 2018; Mortazavi, Raissi, and Mehne, 2018; Weyer, 2016; Evans et al., 2015; Kleinsmann and Valkenburg, 2008). These companies tended to rely on methodologies such as participatory design workshops, interviews and contextual inquiry sessions in flight or driving simulators to involve their customers in the design of new products. In essence, inviting customers to physically take part at the design stages has helped designers to reduce the time required to conduct market research, as well as the errors derived from the use of long-term memory on questionnaires, surveys, and interviews typically used in such type of research (Defeo, Harding, and Wood, 2016; Brabham, 2013).

In the automotive industry, research community started focusing on contextual inquiry in the past decade, and predominantly it involved interviewing drivers while they were inside automobiles (Giuliano, Germak, and Giacomin, 2017; Ramm et al., 2014; Meschtscherjakov, et al., 2011). This method was firstly used by Human-Computer interaction researchers (Wixon, Holtzblan, and Knox, 1990) and it consists of in-context interviewing between customers and designers to create a shared understanding in product usability (Rosenzweig, 2015; Druin, 1999; Coble et al., 1995). Thus, it was reduced the effect of cognitive processes such as the decaying of the memory strength or the location updating effect described in the previous section (Giuliano, Germak, and Giacomin, 2017; Ramm et al., 2014). However, interviewing drivers inside static automobiles or driving simulators not always provided designers with fully realistic information on how automobiles were used (Bella, 2014). Therefore, researchers started exploring the possibility of connecting designers with users in real-time while they were driving (Flor et al., 2019; Martelaro and Ju, 2017; Tasoudis and Perry, 2016). Those researchers advocated for the use of real-time remote contextual inquiry and naturalistic observation for the collection of both customer feedback and improvement ideas in a design-driven lab (Gkatzidou, Giacomin, and Skrypchuk, 2016). Naturalistic observation refers to real-time driver monitoring, and design-driven labs were recently defined as "physical regions in which stakeholders from partnerships of firms and users collaborate for the creation, prototyping, validating and testing of new technologies, services, products and systems in real-life contexts" (Westerlund, Leminen, and Habib, 2018). Thus, it has been recently argued that automotive designers could efficiently conduct market research through the interview of automobile drivers while they were in the automotive habitat lab in order to collect customer feedback and improvement suggestions (Gkatzidou, Giacomin, and Skrypchuk, 2016). In the automotive environment, a design-driven lab can be implemented as follows:

FIGURE 5: AUTOMOTIVE HABITAT LABORATORY CONCEPT (GKATZIDOU, GIACOMIN, AND SKRYPCHUK, 2016)

According to Gkatzidou et al. (2016), the implementation of a design-driven lab in the automotive context would involve remote collaboration among designers and automobile drivers for the collection of customer feedback and discovery of new automotive products and service concepts (Figure 5). Subsequently, they proposed a project entitled *Automotive Habitat Laboratory*. The Automotive Habitat Laboratory project (also referred to as '*AutoHabLab*') was a research project funded by JLR (Jaguar Land Rover) which addressed the implementation of real-time remote collaboration with automobile drivers by defining which human behaviour monitoring technologies, communication protocols and working methods could allow for "real-time creative dialogue" between designers and automobile drivers. As part of such project, the research described across this document adopted a human-centred design perspective to explore the implementation of such real-time creative dialogue for the collection of customer feedback and development of new automotive product and service concepts.

Summarising the current situation, there are inefficiencies and biases in the current automotive design approach due to limitations of human memory and some methodologies used to collect data from automobile drivers.

However, the design process might possibly be improved by new forms of real-time within context collaboration in which designers directly interact with drivers to collect customer feedback and improvement suggestions for the automobile.

One possible form of collaboration which has been investigated by the research which is described in this thesis is contextual inquiry, and the following section discusses the approach proposed to conduct such investigation.

1.6 Research Challenges

According to the literature, contextual inquiry is characterised by the researcher visiting users' work environment and conducting an interview while users perform the work in which the investigation is centred (Berndt et al., 2015). Accordingly, previous implementations of contextual inquiry for automotive applications occurred in either driving simulators or immobile vehicles (Giuliano, Germak, and Giacomin, 2017; Ramm et al., 2014). However, these implementations required respondents to use their long-term memory and as described in section 1.4, this frequently leads to inaccuracies in the data collected. To reduce those possible inaccuracies, this research took the view of contextual inquiry sessions being conducted real-time, while the respondents were driving. On top of that, the length of contextual inquiry sessions typically ranges between 1-6 hours (Berndt, Furniss, and Blandford, 2015) whereas average drivers use their automobiles for 51 minutes per day (Johnson, 2019). This is a time restriction to be considered for the design of those sessions (Strachan, 2007). Previous literature suggested telephone interviews tending to be shorter than face-to-face interviews (Irvine, Drew, and Sainsbury, 2012). Therefore, this research prioritised the implementation of remote contextual inquiry over the face-to-face contextual inquiry.

On the other hand, the automotive context is a complex environment in which many different elements coexist, influencing the experience of driving and in turn, the outcomes of those implementations (Jeon, 2015; Bella, 2014). The elements coexisting in the automotive context (Sliggers, 2015; Jeon, 2015; Portela et al., 2013; Kilpeläinen and Sumala, 2007) which differently affect the experience of driving may have their origin inside the automobile (i.e. media equipment, noise, temperature, passengers, etc.) or outside the automobile (i.e. road type, traffic conditions, weather, pedestrians, etc.), and they alternatively influence automobile drivers (i.e. attention, cognitive load, affect, memory, etc.). Furthermore, customer interviewing involves a range of elements independent to driving which can significantly affect the outcomes of a research study (Lazar, Feng, and Hochheiser, 2017; Spradley, 2016; Schroeder and Epley, 2016; Waytz, Heafner, and Epley, 2014; Nowak and Biocca, 2003; Foddy, 1993). These elements can be the communication channel supporting the interview (i.e. face-to-face, telephone call, email, etc.) personal characteristics of the interviewer (i.e. physical appearance, voice, gender, etc.) or the contents of the interview (i.e. semantics, the structure of the interview, open or closed questions). To date, studies involving collaboration with customers while they were located inside an automobile tended to focus on the outcomes of the collaboration, not fully considering the influence of these elements on the data collected (Giuliano, Germak, and Giacomin, 2017; Cha et al., 2015; Ramm et al., 2014). This leads to the need for further investigation regarding the influence of such elements on the outcomes of real-time collaboration. Therefore, the research described in this thesis aimed to explore the relevance of these elements for the implementation of real-time collaborative sessions between automotive designers and automobile drivers, as well as the applicability and possible benefits of such implementation.

In summary, due to possible limitations in previous implementations of contextual inquiry inside automobiles, the following chapters discuss which concepts and methodologies may influence the implementation of contextual inquiry when it is conducted real-time and remotely, while the respondents are driving an automobile.

1.7 Research Questions

Drawing on the research challenges described in the previous section, the main question this research addressed was "**How can real-time remote contextual inquiry be implemented in the automotive context?"** To be able to effectively and systematically answer this question, four areas of investigation have been undergone relating to the hypotheses stated below across the different chapters of this thesis. These areas of investigation were addressed under the premise that real-time remote contextual inquiry does not represent a threat towards driver's road safety and were selected according to the suggestions made by Gkatzidou et al. (2016), which proposed to prioritise the definition of communication hardware and channel requirements for the implementation of real-time collaborative sessions between automotive designers and automobile drivers. Specifically, the research questions responded through the research were:

a) The characteristics of the communication hardware installed on-board the automobile to support remote collaboration affect the driver while driving and multitasking: Which apparatus can be installed and which specifications should they have?

b) The communication channel used to support the real-time collaboration affects outcomes of the collaboration: What is the optimal method to communicate automobile driver and designer for a real-time remote-collaborative interaction?

c) The interior of the automobile offers stimuli to drivers that affect their answers if they are interviewed while driving: What are the benefits of contextual inquiry when it is conducted remotely while the driver is operating the automobile?

d) The interaction with a designer during real-time remote collaboration influences drivers' affective state: What is the effect that real-time remote contextual inquiry has on drivers' emotions?

Due to the limited body of previous literature implementing real-time remote contextual inquiry sessions in automobiles, it was decided to focus the research on the analysis of key factors to be considered for such implementation. To that end, four areas of research investigation were selected as the basis of the research. The first two of these areas were selected in order to define the minimum requirements for the implementation of on-road contextual inquiry sessions, whereas the following aimed to investigate possible benefits and consequences of such implementation. Specifically, the research aims were: (1) Explore which communication hardware (i.e. screen, speaker, etc.) can be installed on-board the automobile to support real-time remote collaboration between drivers and designers. To that end, it was conducted a literature review on computer-mediated communication technologies which was followed by an exploratory study where some of these technologies were tested in a driving simulator (2) Explore which communication channel (i.e. voice-based communication channel, video-based communication channel, etc.) can be used to create the "virtual presence" of the designer inside the automobile for real-time remote contextual inquiry sessions. To that end, it was conducted a literature review on virtual presence as well as its perception, and such literature review was followed by a simulator study in which alternative communication channels were tested in terms of virtual presence perception. (3)

Explore possible benefits (i.e. quantity of information collected, variety of information collected, etc.) of implementing real-time remote contextual inquiry sessions between designers and automobile drivers while driving. To that end, it was conducted a literature review on interviewing techniques and creativity, it was developed a semi-structured interview to embody the contextual inquiry session, and it was tested in a driving simulator study (4) Explore the effects of real-time remote contextual inquiry on drivers' emotions to assess potential links of these to their road safety (i.e. road rage, declined attention to the road, etc.). To that end, it was conducted a literature review on the cognitive elements involved in driving, and such literature review was followed by an on-road study in which some drivers' emotions were monitored while they were involved in a real-time remote contextual inquiry session.

1.8 Thesis Outline

This document includes 8 chapters:

Chapter 1: Introduction. Discusses the background of current automotive design practices as well as some of their limitations, subsequently analysing opportunities and challenges which have been recently found in the literature.

Chapter 2: Literature review. Includes a first section dedicated to the methodology applied to conduct the literature review (sections 2.1, 2.2, 2.3 and 2.4) and a second section where the findings of the literature review are discussed and summarised (sections 2.5, 2.6, 2.7 and 2.8).

Chapter 3: Methodology. Includes a description of the design philosophies which are frequently adopted by companies for the development products and services. This description is followed by a discussion of the design philosophy adopted in this research, as well as the methods associated with such philosophy, possible limitations and a summary of the methodology.

Chapter 4: Communication hardware requirements for real-time remote collaboration with drivers. Aims to answer the first research question: *Which apparatus can be installed and* *which specifications should they have?* It includes a study in which three communication hardware alternatives were tested to explore their effects on the driver's perception and performance while operating a driving simulator and multitasking.

Chapter 5: Communication channel requirements for real-time remote collaboration with drivers. Aims to answer the second research question: *What is the optimal method to communicate automobile driver and designer for a real-time remote-collaborative interaction?* It includes a study in which two communication channels were tested to explore their influence on the closeness in which their users perceived each other while collaborating remotely.

Chapter 6: Exploring the possible benefits of conducting real-time remote contextual inquiry with automobile drivers. Aims to answer the third research question: *What are the benefits of contextual inquiry when it is conducted remotely while the driver is operating the automobile?* It describes a study in which a number of interviews were conducted in and outside the automobile to explore the influence of driving on the answers collected.

Chapter 7: Exploring the possible consequences of conducting real-time remote contextual inquiry with automobile drivers under real driving conditions. Aims to confirm whether the results of the previous study can be also obtained in real driving conditions as well as to answer the fourth research question discussed in the previous section: *What is the effect that real-time remote contextual inquiry has on drivers' emotions?* To that end, it was conducted a study in which participants were interviewed while driving a real automobile, and their emotions were monitored during the complete driving period.

Chapter 8: Conclusions. Reviews how the research question was addressed, the contribution to the field, its limitations, and suggestions for future lines of work.

2. Literature Review

2.1 Search Themes

As discussed in Chapter 1, the research described in this thesis investigates the implementation of collaborative sessions among designers and automobile drivers through the use of real-time remote contextual inquiry. In order to address the investigation, four areas were prioritised and studied (Figure 6). Those areas were selected in order to address minimum communication hardware and channel requirements, as well as to explore its possible benefits and consequences for drivers' emotions.

Chapter 1: Introduction			
Chapter 2: Literature Review			
Hardware Requirements	**Aim:** Exploring which pieces of hardware and software can be installed inside the automobile to support real-time remote communication.	**Method:** Analysing current Computer Mediated Communication (CMC) and Computer Supported Cooperative Work (CSCW) tools and practices.	**Keywords for literature review:** CMC; CSCW
Channel Requirements	**Aim:** Exploring which methods can be used to create the "virtual presence" of the designer inside the automobile for real-time contextual inquiry sessions.	**Method:** Analysing the nature of real-time remote collaboration and its perception among collaborators.	**Keywords for literature review:** Telecommunication; Telepresence
Possible Benefits	**Aim:** Exploring which benefits can offer implementing real-time remote collaboration for the collection of ethnographic data and improvement ideas for the automobile.	**Method:** Analysing current interviewing practices and guidelines to conduct real-time contextual inquiry.	**Keywords for literature review**: Ethnography; Co-design
Possible Consequences	**Aim:** Exploring the effects of contextual inquiry on the emotions of de driver.	**Method:** Analysing which factors affect the psychophysiological state of drivers and current measurement practices.	**Keywords for literature review:** Human Factors; Emotions
Chapter 3: Methodology			
Chapter 4: Defining Hardware Requirements for Real-Time Remote Collaboration			
Chapter 5: Defining Channel Requirements for Real-Time Remote Collaboration			
Chapter 6: Exploring Possible Benefits of Real-Time Remote Contextual Inquiry			
Chapter 7: Exploring Possible Consequences of Real-Time Remote Contextual Inquiry			
Chapter 8: Conclusions and Future Work			

FIGURE 6: STRUCTURE OF THE SEARCH STRATEGY AND OBJECTIVES OF THE MAIN SECTIONS INVESTIGATED

The keywords which were used to start the literature review (Figure 6) were selected for representing research topics which were frequently present on the references motivating this research and included in sections 1.5 and 1.6.

2.2 Search Strategy

In order to systematically collate relevant published information for a literature review, the research community have proposed alternative methodologies (Boland, Cherry, and Dickson, 2017; Kitchenham, 2004). The literature review conducted in this research was based on the guidelines proposed by Kitchenham (2004) and it included searches in Brunel University's Library, Google Scholar, Research Gate, the Human-Centred Design database (HCDBIB), and other three technical and scientific research databases. These other databases belong to three Spanish universities and were used for being Spanish the native language of the author in order to include resources in a second language into the bibliography. The Spanish universities whose databases were used for the literature review were Universidad Carlos III de Madrid (UC3M), Universidad Complutense de Madrid (UCM) and Universidad Nacional de Educación a Distancia (UNED). During the searches, dictionary synonyms such as 'vehicle' for 'automobile' or 'car' were used for the searchers interchangeably as well as their plurals.

A first attempt to gather relevant published information involved searches containing the words 'co-design + interaction + vehicle' as well as their respective plurals and synonyms (i.e. 'discussion', 'dialogue' or 'conversation' for 'interaction' and 'car' or 'automobile' for 'vehicle'). That search aimed to find literature directly related to the current research. However, such search process did not provide significant findings. Then, a second search process was followed in order to find the most relevant information resources and it involved twelve searches (Table 2).

Communication Hardware		
CSCW + definition / methods / measurement CMC + definition / methods / measurement	CSCW + equipment / tools / technology CMC + equipment / tools / technology	CSCW + automobile / driver CMC + automobile / driver
Communication Channel		
Telecommunication + definition / methods / measurement Telepresence + definition / methods / measurement	Telecommunication + equipment / tools / technology Telepresence + equipment / tools / technology	Telecommunication + automobile / car / driver Telepresence + automobile / car / driver
Interviewing Techniques		
Ethnography + definition / classification Co-design + definition / classification	Ethnography + practices / tools / methods Co-design + practices / tools / methods	Ethnography + automobile / car / driver Co-design + automobile / car / driver
Emotions		
Emotion + definition / methods / measurement Human Factors + definition / methods / measurement	Emotion + equipment / tools / technology Human Factors + definition / methods / measurement	Emotion + automobile / car / driver Human Factors + automobile / car / driver

TABLE 2: KEYWORD SEARCH STRATEGY FOR THE LITERATURE REVIEW

The searches were used to explore four research areas and were divided into three sub-searches, aiming to address specifically key definitions, current practices, and applicability of those areas to the current research (Table 2). For instance, for the analysis of the on-board equipment requirements, the words chosen were 'CSCW' and 'CMC', and to explore their definition, current practices, and applicability to the current research, these words were accordingly combined with words such as 'definition', 'technology', and 'automobile'. The same procedure was followed to conduct searches in regards to the communication channel, the interviewing techniques and the emotions.

Lastly, it was followed an autoregressive strategy in order to increase the robustness of the findings. Thus, when a new semantic was found in more than two independent sources of the literature (i.e. different authors, different institutions, etc.), it was added to the keyword search strategy (Table 2) and the searches were repeated including the new word.

2.3 Inclusion Criteria and Summary of Sources

The primary criterion used to select materials to be reviewed was an assessment of the abstract towards the relevance of the source for the current research. Secondly, a more specific criteria was defined and applied for the inclusion of materials:

- Introduces theory or definitions in regards to one or more of the search themes
- Introduces methodologies or measurement techniques in one or more of the search themes
- Involves an automotive application within one or more of the search themes

The sources which did not meet the inclusion criteria or did not provide additional information to the sources already reviewed were excluded from the review. Books edited by scientific publishers (i.e. Springer, ACM, etc.), journals and conferences with a SCImago Journal Rank (SJR) indicator in the Quartiles 1-2 and authors with an h-index above 10 were prioritised over other sources of information in order to ensure that recently relevant research areas and authors were included into the literature review. This approach might have presented some limitations such as the non-identification of papers-in-progress or early-career publications. However, aiming to reduce this effect, the authors most frequently referenced in the literature review findings were followed in social media such as Research Gate and Academia. Additionally, corresponding keywords alerts were set up in Google Scholar in order to ensure the reception of notifications when relevant articles were published over the research period. A total of 75 books, 245 papers, 24 reports, and 18 websites were reviewed and synthesised.

2.4 Structure of the Literature Review Findings

As discussed in section 1.5, this research followed a Human-Centred Design approach to connect automotive designers with drivers. Therefore, the findings of the literature review were classified according to the principles of the Human-Centred Design pyramid (Giacomin, 2014). Those principles structure design semantics in a pyramid which is divided vertically in five growing layers of complexity. These layers include design semantics associated with specific concepts at the bottom and gradually increase the complexity of their contents towards the top, where the design semantics associated with general concepts are located. Specifically, the semantics proposed for the HCD pyramid by Giacomin (2014) were the following from the bottom to the top: (1) Human Factors, (2) Activities, Tasks and Functions, (3) Interactivity, (4) Semiotics, Communication and Discourse, and (5) Meaning. According to this author, professionals involved in a design process may respectively use those semantics to answer the classical rhetorical questions of antiquity: (1) Who, (2) What, (3) When, (4) In what Way, and (5) Why. Thus, designs whose characteristics are developed considering those semantics can be expected to offer an increased range of affordances to their users.

On the other hand, this research did not aim to develop a specific design. Instead, it was aimed to explore the relevance of some elements involved in driving towards the implementation of real-time remote contextual inquiry sessions. Therefore, the use of the Human-Centred Design pyramid was limited to the classification of the literature review findings into different layers of growing complexity. In this case, due to the varied nature of the proposed search keywords, it was decided to reduce the number of layers of complexity composing the literature review findings. Sinek (2011) suggested that among the rhetorical questions of antiquity, only three were required to guide communication, and these were (1) What, (2) In what Way, and (3) Why. Therefore, the themes found in the literature were clustered in the three main layers of complexity (Figure 7).

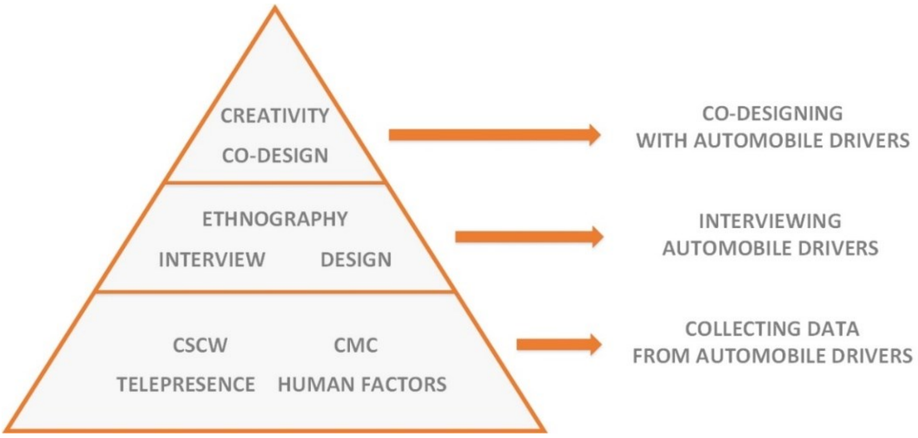


FIGURE 7: RESEARCH THEMES FOUND IN THE LITERATURE CLASSIFIED IN LAYERS OF COMPLEXITY ACCORDING TO THE PRINCIPLES OF HUMAN-CENTRED DESIGN (GIACOMIN, 2014)

Firstly, the findings of the searches which included the keywords ‘CSCW’, ‘CMC’, ‘Telepresence’ and ‘Human Factors’ were assigned to the lowest layer of the pyramid and it was named *collecting data from automobile drivers*. Secondly, the findings of the searches which included the keywords ‘Ethnography’, ’Interview’, and ’Design’ were assigned to the middle layer of the pyramid and it was named *interviewing automobile drivers*. Lastly, the findings of the searches which included the keywords ‘Creativity’ and ‘Co-design’ were assigned to the highest layer of the pyramid and it was named *co-designing with automobile drivers*. The titles of these layers were selected in order to summarise their contents. In turn, in order to provide a wider perspective of the nature, current practices and relevance of the findings for this research, each of these layers was divided accordingly into expanded definition of key concepts, current practices and applicability for the aims of this research.

The findings of the literature review were stored both physically and digitally. The structure of both databases was divided into three areas (Figure 7) and developed in sections 2.5, 2.6 and 2.7, being named respectively *collecting data from automobile drivers*, *interviewing automobile drivers* and *co-designing with automobile drivers*.

Literature Review Findings

2.5 Collecting Data from Automobile Drivers

The driving environment is a highly dynamic context in which a wide range of elements is in continuous change. These elements can be located either inside (i.e. infotainment systems, driver, passengers, etc.) or outside the automobile (i.e. traffic conditions, weather, pedestrians, etc.) and they can contribute to the psychophysiological responses of the driver in different manners (i.e. attention, cognitive workload, affective state, etc.) (Brooks and Rakotonirainy, 2005). For safety reasons towards the drivers, it was explored the nature of these elements prior to exploring the implementation of real-time remote collaboration. Therefore the next sections review the elements involved in driving as well as the methods most frequently used to explore their possible psychophysiological effects on drivers.

2.5.1 Expanding the definition of automobile drivers

As discussed in section 2.1, the literature review partially aimed to explore which pieces of equipment can be used to support real-time remote collaboration between automobile drivers and designers, as well as to create the 'virtual presence' of the designer inside the automobile. In order to create a basic understanding of which elements can affect the selection of such pieces equipment, it was analysed the nature of driving as well as the nature of interacting with virtual presences.

First of all, it is worth noting that the automobile segments this research focused on were the European A, B, C, D and J according to the regulations of the European Commission (EAFO, 2018). These segments were Mini, Small, Medium, Large and Sport Utility cars (EAFO, 2018). This decision was made upon request by the industrial sponsor due to the significant representation of these segments within global automobile sales. These automobile segments were estimated to compose more of 85% of the total automobile sales in 2017, whereas the remaining sales are typically composed of luxury automobiles, sports automobile and others for commercial use such as Vans or Minibuses (ICCT, 2017). Therefore, as mentioned in section 2.2, concepts such as 'car', 'automobile' or 'vehicle' included in this research refer to those segments. In turn, automobile drivers refer to the human users who operate those automobiles.

It is also relevant to note the definition for driving involving different elements and complexities across the literature. Oxford English Dictionary defines driving as operating and controlling the direction and speed of a motor automobile. However, scholars argued that is a complex activity far from such simplistic affirmation (Jeon, 2015). Affect researchers in the automotive context defined driving as a complicated situation that results of the interaction among a number of sub-elements of environmental and human factors.

On the environment side, factors such as noise, weather, temperature or the status or the automobile compose some of the most frequently studied elements (Portela et al., 2013; Kilpeläinen and Sumala, 2007). For instance, automobile drivers are frequently exposed to a number of noises that can be generated by the automobile and its usage (i.e. a conversation between passengers, the engine, the media equipment, etc.) or by the external environment (i.e. other automobiles, weather, etc.). Thus, when there is a conversation inside the automobile, the speech volume can play a critical role to be distinguished from the other sound sources (Sliggers, 2015).

Regarding the human factors involved in the driving task, cognitive elements and mental resources interact with each other, with affective processes and with driving performance. The literature generally prioritised such types of element over the environmental factors in studies related to driving performance. For a basic understanding of the taxonomy of these factors, previous research proposed an affect-integrated model (Figure 8) to represent the key human factors involved in the driving task (Jeon, 2015; Watson et al., 1999).

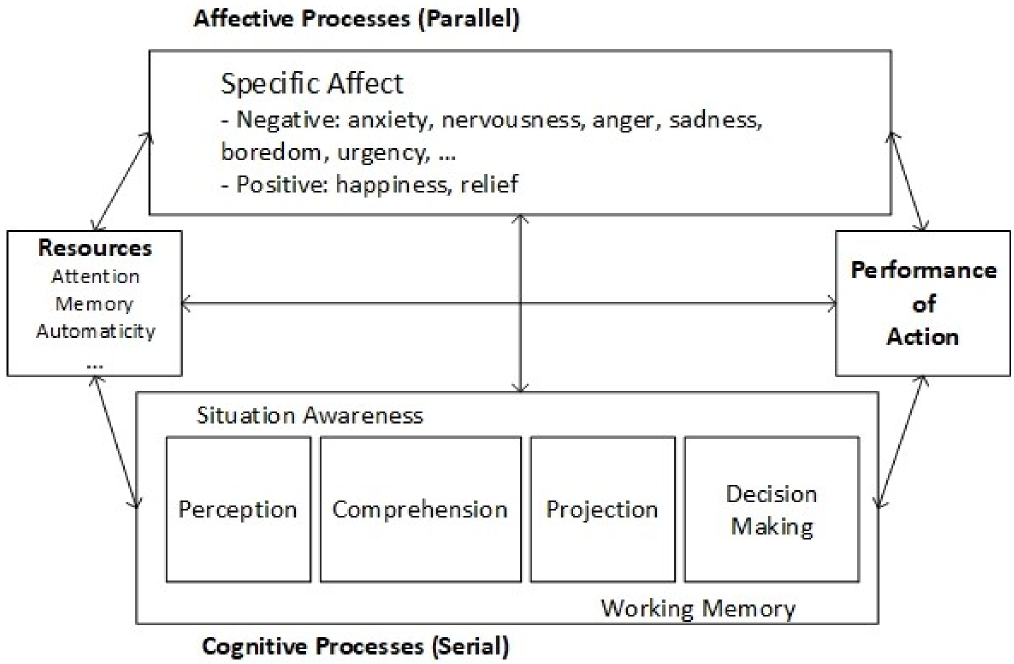


FIGURE 8: AFFECT-INTEGRATED MODEL (JEON, 2015)

Among the elements involved in the affect-integrated model (Figure 8), researchers in the automotive sector tended to prioritise cognitive processes and performance of action, moving the affective processes to a second plane (Jeon, 2015). To be specific, one of the most frequently studied elements is the cognitive load, which has been also referred to as mental effort, mental workload or cognitive workload (Grier, 2016). Instruments used to measure cognitive load usually focus on analysing elements such as activity demands or performance through the use of post-task questionnaires or observation (Grier, 2016; Angell, et al., 2006). Among the possible options, the most widely used instrument is the NASA-Task Load Index (NASA-TLX), which has been used for more than 20 years and specifically aims to measure six independent clusters of variables: Temporal, Mental and Physical Temporal Demands, Effort, Performance and Frustration (Hart, 2006). On the other hand, researchers have used a wider range of approaches for the specific study of performance of action. Some alternatives used to measure drivers' performance are the implementation of eye-tracking-based technologies (i.e. analysing number of fixations on the road, mean X and Y gaze position on the road, etc.), or the analysis of elements related to the driving task (Fleskes and Hurwitz, 2019; Hashash, Zeid, and Moacdieh, 2019). Examples of these elements include the average automobile speed, the average brake reaction time, the steering wheel position, or the count of times which an predefined event occurs (i.e. drivers interacting with pedestrians or with their smartphone, erroneous direction followed when using a navigation tool) (Sheykhfard and Haghighi, 2019; Chen, Zhang, and Wang, 2019; Jeon, 2015).

On the other hand, the interior of the automobile offers to drivers another experience on top of the experience of the factors mentioned in the previous paragraphs. Such experience has been frequently referred to as their *immersion* or *presence* on the road (Wirth, et al., 2007; Lee, 2006; Dant, 2004). Additionally, remote collaboration between automobile drivers and designers requires drivers to directly interact with a virtual presence which embodies the designers inside the automobile (Gkatzidou, Giacomin, and Skrypchuk, 2016). These phenomena are independent, even though the presence of the driver on the road and the interaction of the driver with the virtual presence of the designer share a technology-mediated experience. Therefore, the concepts of presence and virtual presence were analysed in order to create a general understanding of the main cognitive processes experienced by the driver when he or she is engaged in a remote interaction while driving.

The concept of 'presence' is typically referred to as virtual presence, telepresence or even mediated presence and it has been studied by scholars from unrelated fields such as communication (Biocca, 2006), business (Klein, 1998), computer science (Minsky, 1980), psychology (Lessiter and Freeman, 2001) or neuroscience (Riva, 2018). The multidisciplinary background of the researchers investigating this concept led to a lack of unified terminology. However, Lombard et al. (2015) reviewed a significant sample of literature aiming to define the construct of presence and published a range of recommendations to help to avoid misunderstandings among scholars. Subsequently, those researchers proposed the identification of the exact locus of definitions to be conducted upon four fault points:

- Presence and telepresence: According to the suggestions made by Lombard et al. (2015), the term presence should be used referring to phenomena in which technology is not involved (i.e. face-to-face meetings) whereas the longer term 'telepresence' should be used only in any presentation referring to phenomena in which technology is specifically involved (i.e. telephone meetings).
- Objective and subjective: Objective forms of presence or telepresence involve characteristics of the environment that can be easily observed and categorised.

Subjective forms, on the other hand, involve the experiences (feelings, senses, perceptions, etc.) of individuals.

- Social and spatial: social presence phenomena involve entities that are or seem to be alive (i.e. involving the use of computer-mediated communication technologies) while spatial presence phenomena refer to experience or the use of the physical space (i.e. involving teleoperation).
- Medium, remote and virtual telepresence: Medium telepresence refers to phenomena which involves exclusive interaction with technologies themselves (i.e. androids, computers that seem to be 'alive' or robots). On the other hand, telepresence phenomena which involves remote interaction among people can be identified as remote telepresence (i.e. conferencing). Lastly, virtual telepresence phenomena refer to human interaction with objects or people generated by technology itself (i.e. driving simulator).

On the other hand, in a situation in which the driver is operating an automobile while interacting with a designer who is not physically located inside the automobile there are two different 'presences' engaged in the interaction: the spatial presence of the driver and the virtual presence of the designer. Moreover, these presences interact with each other through the use of computer-mediated communication technology, which suggests that social presence can also be of interest for the current research (Lombard, et al., 2015).

In summary, the study of phenomena classified within any of the definitions described in the previous paragraphs usually requires the use of specific methodology, and sometimes such phenomena involves several of these telepresence types (Lombard, et al., 2015). This creates a wide range of possibilities collect data from automobile drivers while collaborating remotely with designers. Thus, the next section explores the most frequent practices to collect data from users in automotive and telepresence applications.

2.5.2 Current data collecting practices

As discussed in section 1.5, researchers investigating the applicability of remote collaboration with drivers while they are operating an automobile have advocated for the use of monitoring technologies in order to understand the constraints and affordances offered by the automotive context (Semmens et al., 2019; Martelaro and Ju, 2017; Gkatzidou, Giacomin, and Skrypchuk, 2016).

According to the literature, tracking the psychophysiological state of the driver has been considered as an effective method to explore user experience on the road (Jeon, 2015; Beghum, 2013; Brooks and Hestnes, 2010). To that end, both objective and subjective (either quantitative or qualitative) data sources are typically collected and combined to track elements such as drowsiness, sleepiness, stress and emotions. These data sources have been frequently measured for research purposes and recently, automobile manufacturers started including monitoring technologies in commercial automobiles. Some of these measures involved data such as changes in the brain activity, heart rate, blood pressure, muscle tension, skin conductance, posture, ocular responses, etc. (Freeman, et al., 2000).

Furthermore, these data sources are similar to those used to measure immersion or presence (Figure 9). Similarly, they both present the difficulty to quantify the effect of specific elements such as the weather or social interaction on multi-dimensional concepts such as the presence or cognitive resources. Since these complex models involve both physical and psychological processes, their measurement has led researchers to face significant challenges to develop reliable and normalised measurement techniques (Baren and IJsselstejin, 2004).

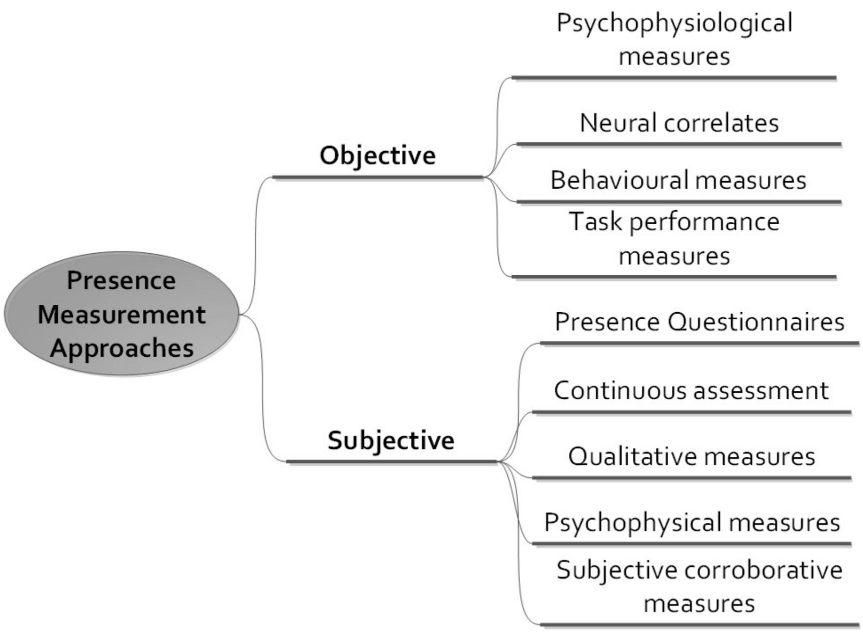


FIGURE 9: FAMILIES OF PRESENCE MEASUREMENT APPROACHES (BAREN AND IJSSELSTEJIN, 2004)

On the one hand, objective measures of presence refer to physiological or behavioural responses that are logically correlated with the participants' psychological responses. Although these measurement techniques sometimes allow real-time monitoring, they have been criticised for being difficult to apply due to being invasive and expensive (Weber, 2017). That is the main reason for Facial Expression Analysis techniques (FEA) to have recently gained popularity among researchers in the automotive industry (Weber et al., 2018). These techniques use the correlation between the emotions and the facial expressions of the driver to monitor affective state and behaviour. In turn, the instruments used for FEA typically consist of either tracking the facial electromyographic activity (fEMG), live observation followed by manual coding of facial activity, or automatic facial expression analysis through the use of computer-vision algorithms (Krosschell, 2017).

On the other hand, for subjective measures of psychophysiological status, the instruments sometimes require the report of an introspective judgment of the study's participant experience. Most of the used solutions included a paper-and-pencil questionnaire right after the activities, due to their apparently valid results and for being an inexpensive method. However, the responses can also be recorded verbally during the experience or following it through an interview (Slater and Steed, 2000) or online during the experiment (Freeman et al., 1999; IJsselsteijn et al., 1998). Although there is evidence that subjective measures can be valid and reliable, these methods have several important limitations such as the accuracy of every participant to reflect his true experience or his intention through the responses to meet (or not) the researcher's expectations. Beyond these problems, which can be addressed with more careful management of the measures or a systematic design, a bigger problem arises: a few researchers used the same set of measurement methods, increasing the difficulty to compare different studies (Baren and IJsselstejin, 2004). However, several presence scale questionnaires that are considered valid and reliable across alternative experimental conditions, participant groups, settings and stimuli, have been developed and widely used (Schubert, Friedmann, and Regenbrecht, 1999; Witmer and Singer, 1998; Lombard and Ditton, 1997; Burgoon and Hale, 1987; Short, Williams, and Christie, 1976).

All the methods presented in the previous paragraphs are typically applied according to the specific needs of the research. Therefore the nature of this research, as well as its goals, require to provide an actual definition for the concept of presence in context. Thus, the next section discusses the most suitable approach for the application of the previous concepts towards implementation of real-time remote contextual inquiry sessions in which automobile drivers interact with the virtual presence of designers.

2.5.3 Application for on-road interviews

The implementation of collaborative design sessions between automobile drivers and design professionals involves the use of technology that supports real-time interaction between collaborators (Martelaro and Ju, 2017; Nevejan, 2009). These collaborators were expected to interact from different locations, which led to select a group of computer-mediated communication technologies: real-time technologies that connect users in different locations (Bostrom, Watson, and Kinney, 1992). Literature also suggested the trust be closely linked to 'successful' creative collaboration and as part of its development, the inclusion of visual and verbal cues was recommended (Chua, Morris, and Mor, 2012; Walther, 2006). For a better understanding of the technologies commonly used for such applications, previous research (Figure 10) summarised the most typical computer-mediated communication solutions used in collaborative work (Walther, 1996; Reinhard et al., 1994; Bostrom, Watson, and Kinney, 1992).

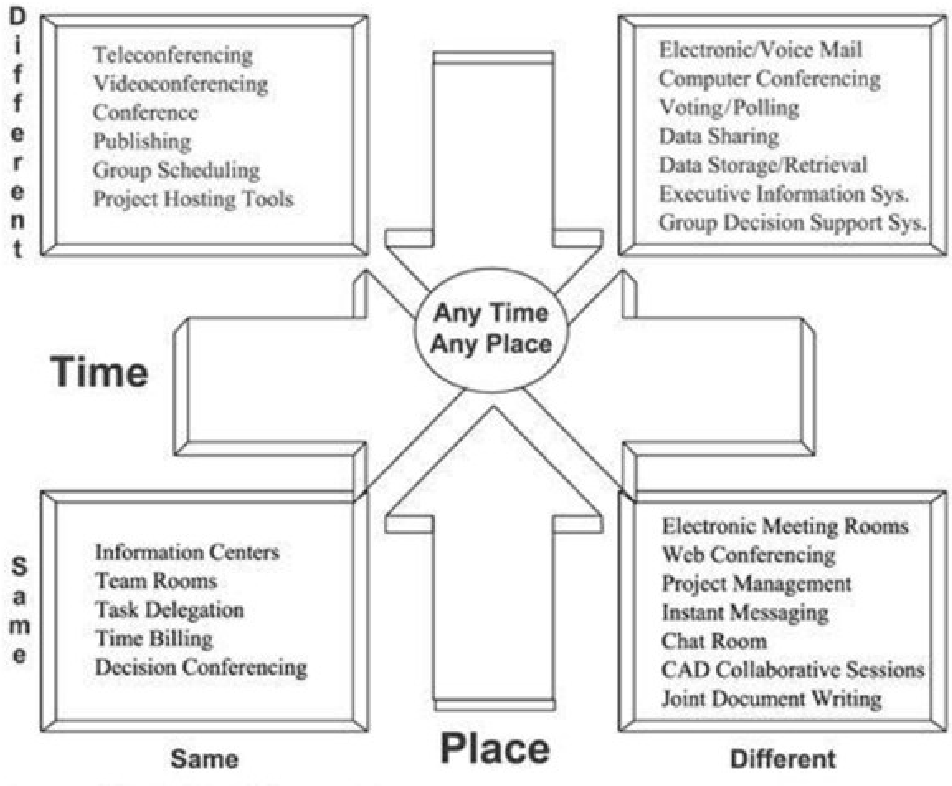


FIGURE 10: TOOLS FREQUENTLY USED FOR COMPUTER SUPPORTED COOPERATIVE WORK (BOSTROM, WATSON, AND KINNEY, 1992)

Among all the technologies frequently used for computer supported cooperative work, (Figure 10), video conference and voice-based conference calls were selected as the options to support collaborative sessions on the road. That selection was due to these solutions communicating users in different locations, which correlated with the approach followed in this investigation in order to remotely connect automobile drivers with automotive designers to conduct real-time remote contextual inquiry sessions. The implementation of these technologies usually requires the use of screens, speakers and microphones for the simulation of virtual presence between collaborators and since current automobiles already include those devices among their on-board equipment, video conference and voice-based conference calls were prioritised in this research. In turn, some characteristics of the on-board equipment which can support a remote collaboration may significantly impact the outcomes of the conversation. For instance, literature highlighted the relevance of the screen size and resolution towards the cognitive load and usage performance of their users (Tanaka, Yamashita, and Okada, 2016; Hancock, Sawyer, and Stafford, 2015; Rümelin and Butz, 2013; Ni, Bowman, and Chen, 2006). Screen size typically refers to the length of the screen diagonal expressed in either inches or centimetres and according to previous studies, the interaction with larger screens may lead to reducing the time to recognise patterns but at the same time it may increase the difficulty to find specific information (Ni, Bowman, and Chen, 2006). Alternatively, screen resolution typically refers to the amount of pixels contained in the screen expressed as the number of pixels along the width of the screen, multiplied by the number of pixel along the height of the screen (i.e. 640 x 320). Screen resolution has been argued to influence task performance based on both subjective and objective data. For instance, the effects of tablet's pixel density were recently investigated by Lischke, et al. (2015) who advocated that the perceived media quality depended on the performed task when interacting with the screen. This suggests that the screen resolution can directly affect the mental workload and perceived media quality of its drivers, depending on the task they are performing.

On the other hand, in regards to the nature of the collaboration, it is worth noting that involves dialogue between the driver and an on-board *virtual presence* that embodies a design professional. According to the literature, three levels of connection between users and virtual presences have been typically studied: text, audio and visual cues (Salinäs, 2002). In the automotive context, implementing text-based chatbots tended to be avoided for safety reasons (Semmens et al., 2019). Therefore, the virtual presence of the designer on-board the automobile was decided to be based on a verbal and/or visual connection between collaborators.

Previous studies analysed the relevance of visual cues to explore how customers perceived the interaction with machines or virtual presences (Schroeder and Epley, 2016; Nowak and Biocca, 2003). This led researchers to argue that autonomous automobiles which interact with their customers through the use of a human voice while driving itself "seems 'smarter', and therefore, more trustworthy" than non-interactive automobiles (Waytz, Heafner, and Epley, 2014). However, the addition of visual cues not always provided as significant results regarding the trustworthiness of a virtual presence as the use of speech (Schroeder and Epley, 2016). This suggests that video conference call can be used to remotely connect designers with automobile drivers, although it may lead to collect similar outcomes from the collaboration as the voice conference call.

Lastly, in terms of metrics, presence studies typically focused on three key issues (Lombard, et al., 2015). These issues were how users perceived their presence towards the virtual world, how users perceived the virtual world, and how users perceived the interaction between themselves and that virtual world (also referred to as social constructs). Other researchers proposed their own constructs for presence. For instance, Lee (2004) defined three domains of virtual experience, one for the physical experience of presence, a second one regarding the interaction with other agents which he calls social presence and lastly a domain referring to the experience of the self in a virtual environment. Alternatively, Nowak and Biocca (2003) defined the concept of presence as the sum of three different constructs named social presence, co-presence and telepresence. These sub-definitions refer to the capacity of the technology to connect users, to the closeness in which the users perceive the connection between themselves and the others and the last one, to the medium's ability to provide the feeling that the users are "there inside the media". Considering these propositions to define presence, the general definition of presence that was used in this investigation was "Presence is the experience of being engaged by the representations of a virtual world" (Jacobson, 2002). In turn, since the collaboration between driver and virtual presence involved an interactive nature, the social constructs of virtual presence were prioritised in this research.

2.6 Interviewing Automobile Drivers

As discussed in section 1.4, research on memory suggested there are several biasing processes hindering the accurate retrieval of lived experiences (Eisenhower, Mathiowetz, and Morganstein, 1991; Bradburn, Rips, and Shevell, 1987). Aiming to reduce such effect, researchers started focusing on how participants feel right now rather than to how they felt when they lived the experience (Stone and S.Shiffman, 1994). Applying this concept to the development of real-time remote contextual inquiry sessions between designers and customers led to study the implications of interviewing drivers while they were operating an automobile reinforcing the opportunities described in section 1.5. Therefore, next sections present several clarifications regarding the most relevant levels in which conducting real-time remote contextual inquiry sessions between designers and customers can be addressed, focusing on the use of interviewing as a research method, current practices and finally on the use of *interview questions as prompt to start a creative dialogue* for the collection of new automotive product and service ideas.

2.6.1 Expanding the definition of interview

Oxford English Dictionary defines Interview as “A meeting of persons face to face, esp. one sought or arranged for the purpose of a formal conference on some point”. In research, it has been defined as “A conversation with the purpose of gathering information” (Berg, 2009). Interviewing is frequently used in a wide range of fields further than research. Some of these fields include human resources recruitment, sales or consultancy (Brudner, 2018; Lundmann, 2017; Strachan, 2007). All these fields tend to impose a set of conditions in which the interview needs to be designed, suggesting that interviews are designed to meet the specific needs of the application. Some of the elements affecting the design of an interview are the goals, timing or the plan to analyse the data (Lazar, Feng, and Hochheiser, 2017). On the other hand, the approach followed to develop the real-time remote contextual inquiry sessions explained across this document tilted to work towards a research-oriented perspective. Hence, a review of the most common qualitative research methods was conducted.

Qualitative research as well as qualitative data analysis represent one of the greatest challenges in research due to the implicit difficulty to normalise its results (Berg, 2009). Therefore, methods designed to gather qualitative data frequently require an especially detailed preparation. Some of the methods most commonly used to collect such data are the in-depth interviews, the focus groups or group discussions and the observation (Hennink, Hutter, and Bailey, 2011). These activities can be simplified in order to ease the data collection and the data analysis stages, or combined to create more complex strategies such as ethnographic studies or qualitative case studies (Table 3).

	Qualitative Research Methods		
High complexity	Ethnographic studies		Qualitative case studies
Medium complexity	In-depth interviews	Focus groups	Observation
Low complexity	Surveys		Questionnaires

TABLE 3: EXAMPLES OF QUALITATIVE RESEARCH METHODS SORTED BY LEVEL OF COMPLEXITY (LIAMPUTTONG, 2017)

In summary, the word ’interview’ will refer in this document to the event in which a set of questions is employed by the designer to collect information from automobile drivers and to prompt a creative conversation through the use of computer-mediated communication technology. Moreover, since this research aimed to study the benefits of conducting interviews while the respondents were operating an automobile, ‘interview’ was used interchangeably with ‘in-context interview’, ‘interaction’, ‘dialogue’ and ‘contextual inquiry’. Regarding the analysis of information potentially collected through the interview, literature tended to focus on four approaches (Thomas, 2006). These approaches (Figure 11) focus on different aspects of the data, which are typically prioritised depending on the specific needs of the study (i.e. most frequent words, meaning, metaphor, etc.).

	General Inductive Approach	Grounded Theory	Discourse Analysis	Phenomenology
Analytic strategies and questions	What are the core meanings evident in the text, relevant to evaluation or research objectives?	To generate or discover theory using open and axial coding and theoretical sampling	Concerned with talk and texts as social practices and their rhetorical or argumentative organization	Seeks to uncover the meaning that lives within experience and to convey felt understanding in words
Outcome of analysis	Themes or categories most relevant to research objectives identified	A theory that includes themes or categories	Multiple meanings of language and text identified and described	A description of lived experiences
Presentation of findings	Description of most important themes	Description of theory that includes core themes	Descriptive account of multiple meanings in text	A coherent story or narrative about the experience

FIGURE 11: COMPARISON OF QUALITATIVE ANALYSIS APPROACHES (THOMAS, 2006)

The implementation of real-time remote contextual inquiry sessions addressed through this investigation focused on the collection of ethnographic data and improvement ideas from automobile drivers, which was expected to correlate with quantity and variety of data (Pedersen, 2019). This information was not expected to explore any theory as the grounded theory approach aims (Corbin and Strauss; 1990), neither to uncover any meaning hidden within the experience explained by the automobile drivers, as the phenomenology approach aims (Glendinning, 2007). Therefore, methodologies such as the general inductive approach and the discourse analysis were prioritised to assess the quality of the information collected from automobile drivers. According to Braun and Clarke (2008) the inductive approach explores key topics covered by respondents beyond the semantic content of the data. This method is based on the codification of raw data into key themes/categories that according to the coders, cover all the collected samples (Thomas, 2006; Lombard, Snyder-Duch, and Bracken, 2006). On the other hand, the discourse analysis is frequently applied to texts and it aims to understand linguistic preferences based on the lexical and semantic contents of the data (Baker, 2006; Trask and Mayblin, 2002).

2.6.2 Current interviewing practices

One of the approaches most commonly used to conduct interviews in research is the ethnographic interview. Ethnography is defined as "a scientific description of the culture of society by someone who has lived in it" (Cambridge English Dictionary, 2018). Additionally, Angrosino (2007) argued that such description needed to include "its institutions, interpersonal behaviours, material productions, and beliefs", which suggests that ethnographic research is closely linked to the interpretation of human behaviour. This research involved collaboration between designers and drivers in order to improve customer experience (see section 1.5), which led to considering the methodologies typically applied in ethnographic research for the development of real-time remote contextual inquiry sessions between designers and drivers.

According to Schensul (1999), the most effective methodologies used by ethnographers are the participant and nonparticipant observation, interviewing and the ethnographically informed survey research. Therefore, the ethnographic interview can be considered a solid scientific methodology to potentially retrieve information through the questions included in real-time remote contextual inquiry sessions. In order to implement such methodology, previous literature included some suggestions (Figure 12).

Questions recommended for in-depth interviews:

- *Descriptive* - Please could you tell me what you do when you get into the car?
- *Narrative* - Can you tell me about how you decided to buy a car?
- *Structural* - So what are the main stages involved in the process of setting up the navigation tool?
- *Contrast* - What are the main differences between driving through a road in good conditions and a road in bad conditions?
- *Evaluative* - How do you feel when you get stuck in traffic?
- *Circular* - What do you think your wife thinks about you as a driver?
- *Comparative* - How do you think the travelling expenses would be if you drove an electric car?
- *Prompts* - Can you tell me a bit more about that?
- *Probes* - What do you mean by 'not clear instructions'?

Questions to avoid:

- *Over-empathic* - I can imagine that driving to work is quite boring, is that right?
- *Manipulative* - You have described your car to consume too much petrol. Is it even worse than that?
- *Leading* - So I do not suppose you would say that you are happy with the satellite navigator of your car?
- *Closed* - So you have been driving for ten years then?

FIGURE 12: QUESTIONS TO USE AND TO AVOID IN SEMI-STRUCTURED INTERVIEWS (SMITH, FLOWER, AND LARKIN, 2009)

Among all these question types, one of them has been widely used in ethnography for decades: the Descriptive question (Spradley, 2016; Schensul, 1999). According to Spradley (2016), the descriptive questions are the most powerful tool to retrieve ethnographic information from respondents. In turn, he classified such kind of questions in five big groups:

Grand Tour Questions: these tools focus on the description of how a specific element usually is. The subject of the question usually ranges from the description of a location to the process to perform a simple task. The goal of these questions is typically to raise the most significant features of a cultural scene. One example of grand tour question is "Take me through a day in your work life".

Mini-Tour Questions: these tools consist of the same principle as the Grand Tour Questions with the difference that they focus on a smaller unit of experience. An example of mini-tour question is “Tell me about the route you usually take to drive to work”.

	Question type
Descriptive	Grand Tour
	Mini Tour
	Experience
	Example
	Native Language
5 W’s + H	What
	Why
	Who
	When
	Where
	How
AEIOU	Activity
	Environment
	Interaction
	Objects
	Users
5 Whys	Why
	Why
	Why
	Why
	Why

TABLE 4: QUESTION TYPES ANALYSED

Example Questions: These questions are designed to retrieve the same type of information as the Grand Tour and Mini-Tour questions but in regards to a more specific focus. Spradley (2016) proposed the use of these questions subsequently to Grand Tour or Mini-Tour questions in order to collect more details about the topic of interest.

Experience Questions: This question type is typically open-ended and focuses on experiences that the interviewees have had in a specific setting. According to Spradley (2016) these questions tend to be difficult to answer for they open nature and therefore, he argued that experience questions tend to provide more accurate answers if are used after asking numerous grand tour and mini-tour questions.

Native-Language Questions: these tools were designed to minimise the influence of informants’ translation competence. When ethnographers use these questions they ask informants to translate, encouraging the use of terms and phrases most commonly used in the cultural scene.

On top of the questions typically used in the ethnographic interview, there are a number of basic questions that usually help researchers to understand the key features of the context under investigation. These questions were summarised in previous literature as the 5 W’s + H, referring to Why, What, Who, Where, When and How (Tattersall, 2015; Mun, 2013; Stringer, 2013 Berg, 2009). The first of these questions, *why*, is used to establish a general focus for the researcher, while the next five are used to identify problems, agents, activities, environments or time in which a specific event took or is taking place.

More recently, other questioning strategies based on the 5 W's +H principle have gained acceptance among researchers due to their simplicity and effectiveness in collecting specific pieces of information. A good example for these strategies is the AEIOU framework, which was developed to either summarising in a worksheet observational notes as they occur or to being used as a set of predefined categories for analysing the data. AEIOU is an acronym for Activity, Environment, Interaction, Object and User, which represent each of the categories to be studied through the interview (Hanington and Martin, 2012).

Similarly to the previous methods, other techniques aim to collect detailed information in a specific topic of interest. To be more specific, Serrat (2017) proposed the use of the 5 Whys to determine the bottom of a specific issue and such method consists of asking *why* consecutively until the respondent stops providing additional information. After reviewing these methods, the questions most frequently used in ethnographic interviews and in the alternative frameworks which typically aim to collect specific information were summarised (Table 4).

On the other hand, interviews are usually applied in research to collect qualitative data based on either the participants' experiences or opinions in regards to a specific topic. That process involves the interaction between an interviewer and a respondent and whole sequence can be summarised in four main stages (Figure 13).

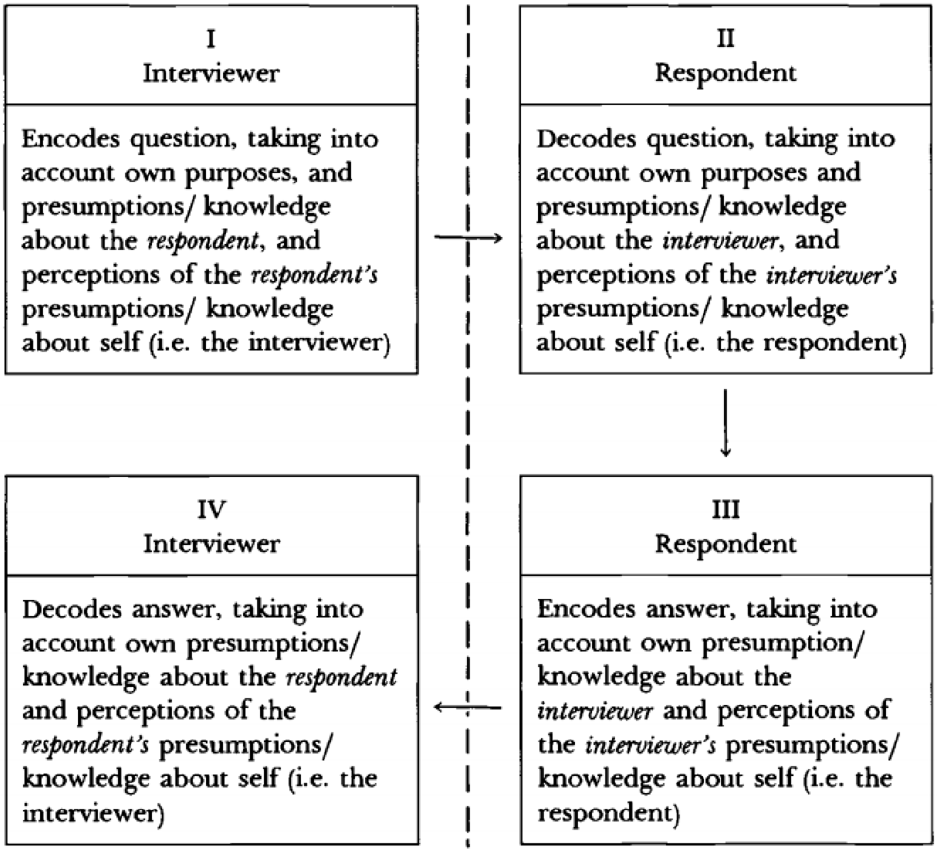


FIGURE 13: MODEL OF THE SYMBOLIC INTERACTIONIST VIEW OF QUESTION-ANSWER BEHAVIOUR (FODDY, 1993)

Foddy (1993) argued that the change between any of these four stages (Figure 13) implicitly creates a window for errors, defining error as the difference between the information the researcher aims to collect and the information collected. Some examples of these windows are the capacity of the respondent to organise and verbalise his thoughts or the simplicity of the vocabulary used by the interviewer in order to make the questions easy to understand. Thus, some of the most typical sources of error when using questionnaires and interviews to collect qualitative data are related to the inability of the interviewer to accurately word the questions, the inability of the respondent to understand the goal of the interview as well as organise his thoughts and verbalise them in a structured and clear manner, and finally from the inability of the researcher to retrieve and analyse the information provided by the respondents. Interviewers only have entire responsibility of the outcomes from the stages I and VI proposed by Foddy (1993), which leads to assuming that a 'well' designed interview should include an accurate definition of its goals in order to avoid misunderstandings with the respondent as well as to encourage respondents to talk lengthily so their perspective about the topic is clearly defined (Foddy 1993; Belson, 1986; Hunt, Sparkman and Wilcox, 1982; Selltiz et al., 1965; Cantril and Fried; 1944).

To conclude the design of an interview three methods have been typically used to check if the questions were appropriately worded (Foddy, 1993; Mangione 1990; Converse and Presser, 1986). These methods included noting if a question was asked to be repeated, asking the respondents to rephrase the questions in their own words, asking interviewees to think aloud as they answer each question and finally doing a double interview, which refers to asking a set of questions once the participant answered the previous ones in order to uncover the respondent's interpretations of key concepts previously discussed. These key concepts can be summarised under the acronym 'TAP', where the initials refer to Topic, Applicability and Perspective. Foddy (1993) argued that the Topic should be properly defined in a manner in which all the respondents clearly understand what the subject of the interview is, also proposed the Applicability of all the questions to each respondent to be ensured, so they are never asked to provide information that they do not have and finally, advocated for the Perspective that respondents should adopt to be specified in order to each respondent providing the same type of answer. During real-time remote contextual inquiry sessions with automobile drivers, this can be undertaken through a small introduction to the drivers in order to inform them in regards to the reasons to undertake the interaction while they are driving and the topic the designer aims to discuss.

Lastly, it is also worth noting that there is a range of elements external to the language itself that directly can affect the outcomes of the interview. Gubrium et al. (2012) suggested the use of intonation, the modification of the speech pacing are key points to achieve a successful interview. Moreover, according to those authors, the environment also plays a critical role in the outcomes of an interview. Some of these elements are the perceptions of formality, warmth, distance, familiarity or even privacy (Knapp, Hall, and Horgan, 2014). However, due to the dynamic nature of driving, these elements could be ignored by the driver due to attention limitations (Jeon, 2015). This leads to question the extent to which the interior of the automobile can affect the outcomes of an on-site interview, which is discussed in chapters 6 and 7.

2.6.3 Application for on-road co-design sessions

Following the design strategy proposed by Lazar et al. (2017) to develop an interview, the next issues addressed were the definition of the goals and the structure of the interview. As mentioned in section 1.6, one of the aims of this research was helping designers to collect ethnographic information and ideas to improve the automobile through the use of real-time contextual interviewing. This clearly defined the main goal of the dialogue. In regards to the structure of the interview, Smith et al. (2009) suggested semi-structured interviews that are effective for data collection based on user experience:

> *"To design data collection event which elicits detailed stories, thoughts and feelings from the participant […] semi-structured, one-to-one interviews have tended to be preferred […]. One-to-one interviews are easily managed, allowing a rapport to be developed and giving participants the space to think, speak and be heard. They are therefore well-suited to an in-depth and personal discussion."*

One step further in the definition of the interview's structure is the design of its semantics. The first formulation of narrative structure is more than 2,000 years old and was proposed by Aristotle (Butcher, 2015). In his analysis, he promoted the division of stories in three parts: the *protasis* introducing the setting, the middle of the play (also called *epistasis*) containing the main action of the story and the *catastrophe* composing the final resolution. This approach has been criticised due to its simplicity and some other proposals have gained popularity in the last centuries (Thompson, 1999; Field, 2005; MacEwan and Freytag, 2016). Among these recent theories, Freytag's pyramid (MacEwan and Freytag, 2016) has been increasingly popular. This structure is based on five steps (Figure 14) and such steps are inspired by Aristotle's proposal of an introduction, a climax and a catastrophe (in this case called Denouement) but in order to create a more fluent sequence of events, Freytag's pyramid also includes a rising and falling action previously and after the climax.

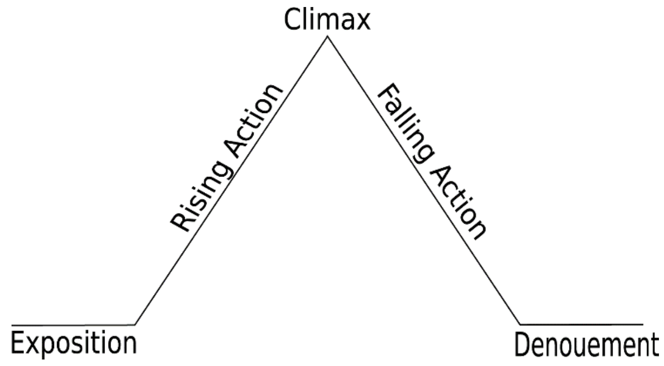


FIGURE 14: FREYTAG'S PYRAMID (MACEWAN AND FREYTAG, 2016)

On the other hand, another approach has been widely used to build conversations. This approach is *the ladder of abstraction* and recently has gained importance in research, focusing on the semantic meaning of the language (Malhotra, 2007; Piker, 2003; Hayakawa, 1991). With such approach, Hayakawa (1991) proposed the use of a ladder as a metaphor where its higher position is occupied by abstract ideas (i.e. wealth, happiness, etc.) and the lowest part was defined by specific concepts (i.e. automobile, book, etc.). When applying this concept to storytelling, Hayakawa argued that ‘good’ storytellers can be defined as those who can effectively fluctuate on the ladder of abstraction while average storytellers tend to include abrupt shifts between the different levels of reasoning. By adopting this approach to the structure of an interview where the goal is to collect customer feedback and ideas to improve a product, the most suitable solution is the adoption of high level concepts to introduce the conversation, the application of specific words to define and develop the ideas and the generation of abstract ideas to close the dialogue.

To provide a guide for the design of questions and interviews, Strachan (2007) proposed shown the 5 Processes Framework, which can be considered as a combination between Freytag’s pyramid and Hayakawa’s ladder of abstraction, applied to the structure of an interview (Table 5).

Opening a session	Enabling Action	Thinking Critically	Addressing Issues	Closing a Session
1. Getting to know one another 2. Clarifying expectations 3. Building commitment	1. What? (Observation) 2. So what? (Reflection) 3. Now what? (Action)	1. Making assumptions and perspectives explicit 2. Understanding interests and power relationships 3. Exploring alternative ways of thinking and acting 4. Making ethical choices	1. Understanding the situation 2. Clarifying the issues 3. Generating options for action 4. Testing options for action 5. Making a decision 6. Taking action	1. Looking backwards: wrapping up the process 2. Looking forward: considering the next steps

TABLE 5: FIVE PROCESS FRAMEWORK (STRACHAN, 2007)

Besides, previous literature supports the use of short and simple questions to build compliance with the interviewees (McLeod, 2014). Compliance refers to social influence which occurs when an individual follows one or more requests suggested by another individual. One of the most popular techniques used to build compliance is typically referred to as "The foot in the door technique" and it assumes that agreeing to a small request increases the likelihood of agreeing to a second, larger request (Freedman and Fraser, 1966). In this context, the foot in the door technique was included in the contents of the real-time remote contextual inquiry sessions in order to, by answering simple questions, increase the likelihood of the automobile drivers answering more complex questions.

In summary, the structure of the real-time remote contextual inquiry sessions can be defined by some of the qualitative research methodologies previously discussed and among all the options, the use of one-to-one semi-structured interview questions was selected as the most suitable approach *to prompt a creative discussion*. Furthermore, the Five Processes Framework proposed by Strachan (2007) was selected to compose the structure of the interview in order to provide 'fluency' to the dialogue (Table 5). Since the aim of these contextual inquiry sessions was collecting ethnographic data and improvement suggestions for the automobiles of the future, the sampling method focused on participants who were holding an active driving license and were accessible to the main researcher regardless of their driving experience (Hutchinson and Sutherland, 2019). In order to recruit interview participants, it was used a mailing list from Brunel University. Once some participants were recruited via email, they were kindly asked to recruit further participants for the study among people they knew.

In order to analyse the data collected in contextual inquiry sessions, four different approaches were considered as described in section 2.6.1. Among these approaches, two methods are frequently used in the automotive context. These methods are the general inductive approach and discourse analysis (Giuliano, Germak, and Giacomin, 2017; Cha et al., 2015; Ramm et al., 2014). The general inductive approach is typically used to identify key themes of interest covered by the respondents and it is considered the simplest among these methods (Thomas, 2006), whereas discourse analysis aims to understand how people use language to create and enact identities through the study of *messages* in terms of linguistics and semiotics (Starks and Trinidad, 2007; Baker, 2006). In this research, it was decided to use both of these two methods. This decision was made in order to collect both improvement ideas and ethnographic data from automobile users as described in section 1.5. Thus, the general inductive approach explored key improvement areas suggested by drivers and discourse analysis addressed the possible effects of driving on the cognitive state of the drivers through the analysis of their speech (see section 1.4 for further detail).

2.7 Co-designing with Automobile Drivers

As mentioned in section 1.5, recent research highlighted the opportunity of improving current practices during the design process in the automotive industry through the implementation of a method which allow designers to solicit the feedback of automobile drivers during routine activity (Gkatzidou, Giacomin, and Skrypchuk, 2016). That opened the door to develop a direct line of communication between drivers in automobiles and design professionals to support a creative conversation as part of a co-design approach (Martelaro, 2017; E. Von Hippel, 2005). Previous sections addressed the applicability of real-time remote interaction between drivers and designers in terms of Human Factors and Interaction (see section 2.4). In order to increase perspective in the potential benefits of such interaction for automotive designers, it was also analysed the concept of co-designing with automobile drivers. Therefore, next sections present several clarifications found in the literature in regards to the *implementation of the* *co-design approach with drivers to collect creative ideas for the improvement of the automobile*.

2.7.1 Expanding the definition of co-design

Oxford English Dictionary refers to the prefix 'co-' as an element used to form nouns, adjectives and verbs that involve commonality, mutuality or the execution of a verb "together with another or others". Additionally, it defines 'design' as "the act of producing a plan or drawing of something before it is made". The combination of both definitions would, therefore, state the meaning of co-design as *the act of producing a plan or drawing of something together with another or others before it is made*.

To date, the concept of designing has been typically represented as a sum of sub-processes whose nature changes depending on the context in which the whole model is defined. Most of the activities typically related to the design process were developed in Academia and have allowed companies to design their products both strategically and efficiently (Clarkson and Eckert, 2010). However, the struggle to adopt a generic design process for different products has been widely recognised to be an issue, due to the specific needs to the alternative markets (Yan, Chiang, and Chien, 2014; Guo, 2010; Hsu, 2009; Brown, 2008). In order to frame the current situation, three design areas were analysed. These alternatives were Participatory Design, Human-Centred Design, and Creative Design, being Co-design considered as the result of the combination between these disciplines (Sanders and Stappers, 2014).

Participatory Design (also called 'co-creation') is a movement which emerged in the 1970s in Scandinavia and is based on the user participation at the design stage of the products (Sanders and Stappers, 2008; Cross, 1971). According to the literature, the idea-generation stage typically accompanies the outset of a new project and includes three main stages: *Groundwork, Co-creation Workshop and Development* (Youngok, Vere, and Youngeun, 2016). These steps can be in turn, divided into some more detailed phases: *Preparation, planning, workshop management, result analysis, building from ideas and learning from processes*.

More recently, it was proposed the use of the Human-Centred Design approach to address the design of products and services which are physical, perceptual, cognitive and emotionally intuitive (IDEO, 2015; Giacomin, 2014). This model is composed of three phases, starting on the users and ending with the product: the first phase is *Inspiration* and it involves the learning of the key needs of the "ultimate customer", the second stage termed *Ideation* refers to the processing of all the information previously learnt for the development of solutions, and lastly, the *Implementation* phase includes all the processes required to actually build the solution previously defined.

On the other hand, literature usually relates Creative Design with innovation (Runco, 2014; Kelley and Littman, 2005). Creative design approaches focus on applying the best strongest attributes of all the stakeholders in the production chain. Professionals with different backgrounds provide alternative perspectives to face the challenges that innovation involves and the cooperation between those individuals compose the core of the activities to develop creative ideas (IDEO, 2015). Kelley et al. used a metaphor of "ten personalities" to define the duties that any innovative company needs to perform (Kelley and Littman, 2005). These duties belong to three different roles, which are *learning*, *managing* and *building*. Furthermore, the creative design has been studied by cognitive psychologists over the years and ultimately Howard et al. (2008) classified the most used creative process models to make them comparable (Figure 15). The steps that most commonly were followed by researchers of the field are presented in the following:

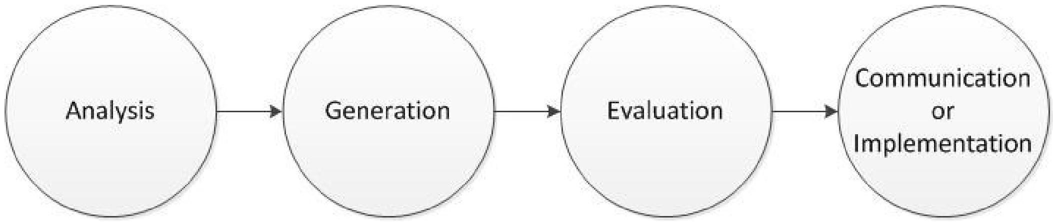


FIGURE 15: MAIN PHASES FOR THE CREATIVE DESIGN PROCESS (HOWARD, CULLEY AND DEKONINCK, 2008)

In summary, there is a number of different paths to approach the design process of a product or service and according to the specific needs of the project, a more limited range of solutions can be used. In the context of the current research and after reviewing the disciplines numbered in this section it can be concluded that co-designing is *the act of producing a plan of something together with the automobile drivers before it is made*. In regards to the definition of the sub-levels for the co-design process, most of the proposals previously reviewed share a common sequence that can be summarised according to the four-step model proposed by Howard et al. (2008): *Analysis of the situation, Generation of ideas to improve the situation, Evaluation of the ideas to improve the situation and Communication / Implementation of the ideas that 'better' improve the situation (Figure 15)*.

2.7.2 Current co-design practices

Over the last decades, the design process was characterised by the use of sketches and iterative modelling by professionals in separated disciplines such as industrial design, graphic design, architecture or interior space design. The communication used to take place either face-to-face or over the phone, or through regular mail (Sanders and Stappers, 2014). With the implementation of agile methodologies such as Extreme Programming, Scrum, or Lean Development, companies started connecting their departments in order to reduce expenses and increase the effectiveness of their teams (Cohen, Lindvall, and Costa, 2004). This, in turn, made departments related to design to merge. Thus, designing after the 1980s increasingly became a collaborative process where professionals in Research and Design have frequent contact with other stakeholders and users (Figure 16).

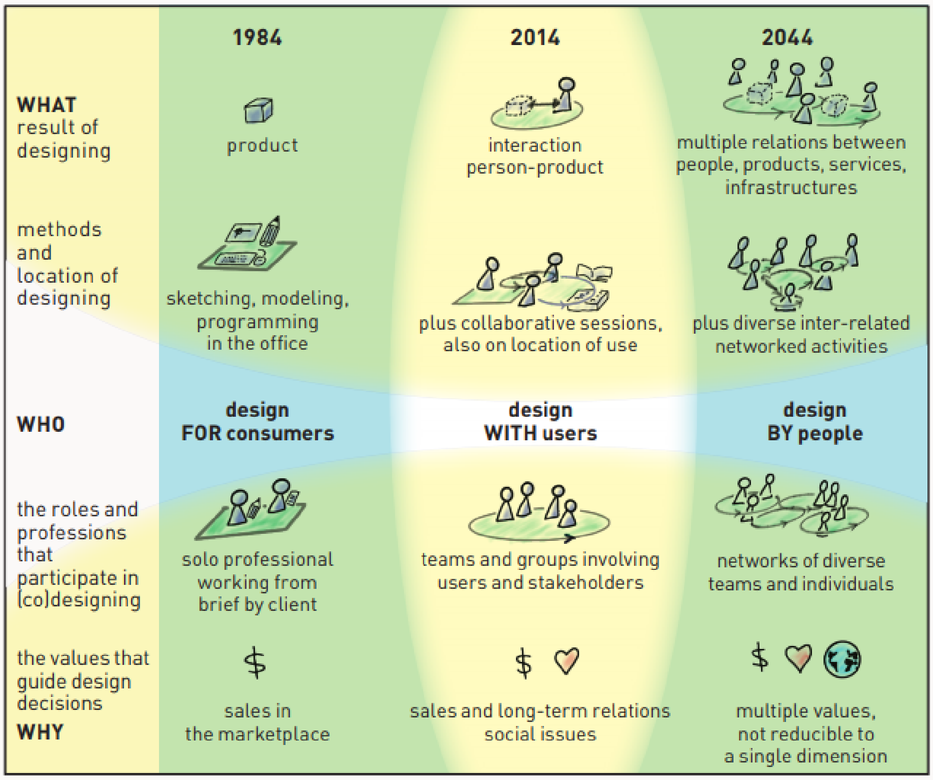


FIGURE 16: OVERVIEW OF THE EVOLUTION FROM DESIGN TO CO-DESIGN PRACTICES (SANDERS AND STAPPERS, 2014)

As part of this increasing tendency to include collaboration to the design process, a growing body of companies developed design-driven labs to pursue open innovation (Westerlund and Leminen, 2011). Design-Driven Labs have been also referred to as 'Living Labs' and can be defined as physical regions in which stakeholders form partnerships of firms and users in order to collaborate for the design and testing of new technologies, services, products and systems in real-time or real-life contexts (Westerlund, Leminen, and Habib, 2018). According to Wang and Oygur (2010), there are four forms of collaborative design depending on the stakeholders taking part in the design activities. These forms of co-design can be 'departmental' when they involve professionals within a single department of a company, 'intra-organizational' when they involve different departments of a company, 'inter-organizational' when they involve professionals of different companies or 'extra-organizational' when they involve the input of end-users of a product or service. Moreover, depending on the specific needs of the project, companies focus on collaborative activities which can take place while stakeholders are using the product or service under development (onwards referred to as real-time collaboration), while they are in a real-life context (onwards referred to as in-context collaboration), or while they are located in a separate room exclusively dedicated to the co-design activity (onwards referred to as co-design collaboration). These different approaches to collaborative relationships in design-driven labs have been widely discussed in the literature and it has been argued that alternatively, they present both benefits and limitations as discussed in sections 1.4 and 1.5 (Giuliano, Germak, and Giacomin, 2017; Schuurman, Marez, and Ballon, 2016; Gkatzidou, Giacomin, and Skrypchuk, 2016; Cha et al., 2015; Westerlund and Leminen, 2011; Björgvinsson, Ehn, and Hillgren, 2010). Some examples of design-driven labs projects were analysed (Table 6). Such analysis included projects in which a collaborative approach was followed, as well as further information regarding the nature of the collaborative activities which those projects involved.

Project title	Research area	Source of collaborators	Real-time collaboration	In-context collaboration	Co-design collaboration
TALIA	Social Innovation	Extra-organizational			X
U4IoT	User Engagement	Extra-organizational	X		X
UNaLab	Smart Cities	Inter-organizational			X
SISCODE	Social Innovation	Inter-organizational			X
EUSIC2018	Social Innovation	Extra-organizational		X	X
PELARS	Education	Extra-organizational			X
FIspace	Logistics	Intra-organizational	X		
ECIM	Transportation	Inter-organizational	X		
AUTOHABLAB	Transportation	Extra-organizational	X	X	X

TABLE 6: EXAMPLES OF PROJECTS INVOLVING DESIGN-DRIVEN LABS (ENOLL, 2019; GKATZIDOU, GIACOMIN, AND SKRYPCHUK, 2016)

Regardless of design-driven labs, it is worth noting that the collaborative methods usually depend on the specific objectives of the project. According to Spinuzzi (2005), the objectives of a co-design activity can be *initial exploration*, *discovery or development*, and *prototyping* (Figure 17). Based on those objectives, scholars tend to follow one or more approaches among the following:

FIGURE 17: CODESIGN METHODOLOGIES CLASSIFIED ACCORDING TO THEIR OBJECTIVES (SPINUZZI, 2005)

Among these methods, the most common practices to co-design are observation, interviews and group sessions for discovery processes (Grocki, 2014; Sanders and Stappers, 2012; Steen, Manschot, and Koning, 2011; Spinuzzi, 2005). These methods generally involve an ethnographic perspective and tend to include descriptive questions in the interviews, and to include the use of pens, post-its, paper and art supplies in the group sessions (Sanders and Stappers, 2014; Howard, Culley and Dekoninck, 2008; IDEO, 2005).

In transportation industries, companies which commercialise trains and aircrafts tended to collaborate with users via semi-structured interviews, questionnaires and activity monitoring (Dillard, Orhan, and Letsu-Dake, 2016; Lanzotti et al., 2009; Olsson and Jansson, 2005). These activities can be undertaken in simulators and in real-life situations. Similarly, professionals conducting research in the automotive sector tended to rely on interviews and design workshops to collaborate with users, although a significant part of these are undertaken either in driving simulators or away from an actual automobile ((Stevens et al., 2019; Giuliano, Germak, and Giacomin, 2017; Weber, 2017; Ramm et al., 2015; Cha et al., 2015).

2.7.3 Creativity of Co-design

As discussed in section 2.5.3 automobile drivers are cognitively influenced by the interior of the automobile, which hinders implementing some of the co-design methods described in the previous section. Thus, co-design methods which do not require the use of materials were prioritised to shape the real-time remote contextual inquiry sessions. Among the options described in the previous section, the interview was selected as the most suitable option to shape the dialogue between collaborators while the driver is operating an automobile due to its low intrusiveness (Hanington and Martin, 2012). Thus, the use of interview questions was proposed to prompt a "creative dialogue" according to suggestions in previous literature (Gkatzidou, Giacomin, and Skrypchuk, 2016).

Over the past decades, the concept of creativity has proven to be difficult to define and measure due to its complex and multidimensional nature (Runco, 2014; Kaufman, Plucker, and Russel, 2011; Plucker and Maker, 2010; Treffinger et al., 2002; Glor, 1998). This suggests the need for a deeper analysis of its meaning in order to provide an operational definition for "creative dialogue". Oxford English Dictionary defines Creativity as "*The use of imagination or original ideas to create something"* however, the existence of a vast amount of research aiming to understand and develop such concept questions the applicability of the previous definition for other uses besides of the quotidian (Said-Metwaly, et al., 2017). A recent literature review in creativity analysed more than 152 papers and concluded that to date, there was no common framework among researchers to define and measure creativity (Said-Metwaly, et al., 2017). However, those researchers noticed that definitions of creativity typically reflect at least one of four different perspectives (Table 7). Such perspectives were the following: cognitive processes associated with creativity ('process' approach), personal characteristics of creative individuals ('person' approach), creative products or outcomes ('product' approach), and the interaction between the creative individual and the context or environment ('press' approach). A more detailed explanation of such perspectives is summarised in the following:

Approach	Focus	Conception of Creativity	Instruments	Advantages	Weaknesses
Process	Creative processes or skills associated with creativity	Domain-general	WKCT (Wallach & Kogan, 1965); TTCT (Torrance, 1966, 2008); SOI (Guilford, 1967); CAP (Williams, 1980)	Widespread utility High reliability Standardized criteria for interpreting scores	Limited scope of measurement conflicting evidence for validity Bias due to scoring and sample size
Person	Personality traits or creative achievements	Domain-general or domain-specific	HDYT (Davis & Subkoviak, 1975); CPS (Gough, 1979); HCAY (Raudsepp, 1981); CBI (Hocevar, 1979c); CAQ (Carson et al., 2005); BICB (Batey, 2007)	Ease of use High reliability Standardized criteria for interpreting scores	Limited scope of measurement Low validity of self-reports Bias due to self-reporting Neglect of differences in creative personality across domains Low sensitivity to training Skewed scores
Product	Creative products	Domain-specific	CAT (Amabile, 1982)	Similar to evaluating creativity in real-life High reliability High validity	Limited scope of measurement Difficulty in selecting judges Bias due to judges Expensive and time-consuming Lack of standardized criteria
Press	Work environment or climate	Domain-general	SSSI (Siegel & Kaemmerer, 1978); CUCEI (Fraser et al., 1986); WES (Moos, 1986); WEI (Amabile & Gryskiewicz, 1989); KEYS (Amabile et al., 1996); TCI (Anderson & West, 1998); SOQ (Isaksen et al., 1999)	Explore whether a work environment is supportive or inhibitive of creativity Evaluate the environmental improvement attempts and corrective actions	Limited scope of measurement Lack of research-based evidence Debate about "climate" meaning and measurement level Individual differences in conception of climate

TABLE 7: APPROACHES TO MEASURING CREATIVITY (METWALY, KYNDT AND NOORTGATE, 2017)

Among the different approaches found in the literature to address the definition and measurement of creativity, the *product* approach introduced by Said-Metwaly et al. (2017) was prioritised in this research. This decision was made due to this approach focusing on creative outputs, which aligned with suggestions made in previous literature (Gkatzidou, Giacomin, and Skrypchuk, 2016). Thus, the operational definition of creative dialogue stated as the "*dialogue between collaborators that involves the development of creative outcomes*".

In this case, the outcomes of the dialogue were the answers provided by the drivers and the assessment of creativity was recommended to be conducted by a panel of experts according to the literature (Amabile, 1983). Previous literature suggested that the validity of the results strongly relies on the panel of experts' qualification, which makes desirable the application of rigorous selection criteria to gather the appropriate group of specialists (Kaufman, et al., 2010). Methods for stakeholder mapping (Newcombe, 2003; Howard, Vidgen, and Powell, 2003), and consensus achievement (Rodriguez, 2006; Hasson, Keeney, and McKeena, 2000; Williams and Webb, 1994) can be applied in order to define selection criteria for the panel of experts. Among the methodologies involving the selection of experts, the Delphi method provides a detailed set of guidelines widely used in social sciences which can be used for both defining selection criteria for the panel of experts as well as for analysing their opinions regarding the definition and evaluation of creativity. This methodology consists of an iterative multistage process designed to transform opinion into group consensus (Hasson, Keeney, and McKeena, 2000). Likewise, with the CAT, the validity of the outcomes generated by the Delphi method relies on the members of the panel, which in the past led researchers to propose some requirements to select the experts systematically (Williams and Webb, 1994).

Essentially, the Delphi technique consists of questioning a panel of experts regarding specific issues. The information concerning the research is typically posted individually to each expert, who is expected to analyse it and subsequently respond to the researcher (Williams and Webb, 1994). Later, the individual replies of the panel are scrutinized and organised by the researcher, who compiles a summarised list for re-submission to the experts. Then, the members of the panel are proposed to reconsider the list and respond indicating whether they agree or not with the selected items. At this stage, the replies are collated again, iterating until consensus is achieved. Literature supports the use of the Delphi method for the collection of quantitative and qualitative data (Rodriguez, 2006) and in the case of creativity assessment, both sources of information can be potentially applied (Hasson, Keeney, and McKeena, 2000). This tool has been criticised and according to Williams and Webb (1994), three key factors need to be explained in detail. These are the definition for consensus, the size of the expert panel and the selection criteria for its members.

Williams and Webb (1994) argued that the meaning of consensus is poorly explained in studies where the Delphi technique is applied, which leads to a reduction of the reliability of their outcomes. On the one hand, a dictionary definition states that consensus is 'A general agreement' (OED, 2018). On the other hand, it has been argued that including numbers to the definition of consensus increases its reliability. However, these numbers usually range from 51% (McKenna, 1994) to 80% (Green, et al., 1999), which suggests the definition of consensus to be adaptable for each study.

In regards to the size of the expert panel, most of the studies found in the literature included panels composed of a range of 10 to 18 members (Okoli and Pawlowski, 2004). However, specific studies involved the use of panels with a range of 4 experts and 1685 experts (Skulmoski, Hartman, and Krahn, 2007; Williams and Webb, 1994). This supports the definition of the specific needs of a study prior to start sampling data.

Lastly, Williams and Webb (1994) suggested that selection criteria for the expert panel needs to be defined. This is due to the versatility of the term 'expertise' depending on the field in which a study is conducted. In the last decades a concept has been increasingly used in the fields of philosophy and economics and it is called '*The Wisdom of Crowds*' (Surowiecki, 2004). This concept refers to the knowledge that a crowd can collect and its capacity to outperform the knowledge gathered by any single individual. Besides, literature typically include lists of suggestions to be fulfilled previous to consider a crowd as *wise* (Origgi, 2018; Surowiecki, 2004). The requirements most frequently recommended are:

1. **A diversity of opinion:** each individual of the crowd should have private information.
2. **Independence:** the opinion of each individual should not be influenced by others'.
3. **Decentralization:** all the members should be able to work based on local knowledge.

4. **Aggregation:** to analyse the data it is imperative the presence of mechanisms that turn individual judgements into collective decisions.

More recently it has been argued a fifth condition to be crucial for “accelerating” the collective filtering of information, which is the presence of a rating device. This referred members of the crowd be asked to produce a rating hierarchy in order to ease reaching consensus (Origgi, 2018).

In summary, according to the literature in Creativity research, there are four main approaches to address the definition and measurement of Creativity. These approaches focus on the study of creative processes, creative people, creative products and creative environments (Said-Metwaly, et al., 2017). In the case of this research, the aim of the contextual inquiry session was to start a creative dialogue between automotive designer and automobile drivers. Therefore, *creative process* and *creative product* were prioritised over the other alternatives (‘creative people’ approach focuses on the personality of the individual and ‘creative environment’ is strongly related to how companies can use the work environment to encourage creative achievement). Applying these approaches to the interviewing context, the creative process approach was used to design the body of the interview (i.e. number of questions, aims of the questions, etc.), and the creative product approach was used to evaluate how creative were the answers collected from the drivers (see section 2.6.3 for further detail). Lastly, the approach selected to explore how creative were the answers collected from the interviews was the ‘product’ approach described by Said-Metwaly et al. (2017) and it advocated for the assessment of creativity in a piece of work by hand of an expert panel specialised in the field of the specific study. This expert panel was asked to provide a definition for creativity and subsequently to assess how creative was such piece of work.

2.8 Summary of the Findings

As discussed in sections 2.1 and 2.2, a literature review was conducted to explore which concepts and methodologies may influence the implementation of real-time remote collaboration between automotive designers and drivers via real-time remote contextual inquiry sessions. The key findings of the Literature Review were summarised to provide an insight into the most inspirational sources as well as a brief description of their relevance for this research (Table 8).

Research Area	Contribution	Source
Aims of the Research	Supporting Ideas	Martelaro and Ju, 2017
		Gkatzidou, Giacomin, and Skrypchuk, 2016
Cognitive elements affecting real-time remote collaboration	Human Factors Applied Model	Jeon, 2015
	Theory of Presence	Lombard et al., 2015
	Presence Measurement	Baren and IJsselstejin, 2004
Interacting with automobile drivers	Interview Design	Strachan, 2007
	Question Design	Foddy, 1993
Co-designing with automobile drivers	Design Methods	Martin and Hanington, 2012
	Theory and Measurement of Creativity	Said-Metwaly, Noortgate, and Kyndt, 2017

TABLE 8: SUMMARY OF THE MOST RELEVANT FINDINGS OF THE LITERATURE REVIEW

After classifying the findings of the literature review, some observations were highlighted as relevant for this research. Such observations were mostly associated with the limited amount of ethnographic information that automotive companies use for the development of new automobiles, which leads to a gap between those companies and the users of their products and services:

- Limited literature involving real-time collaboration with drivers inside automobiles. Common practices of collaboration with automobile drivers include design-based workshops in dedicated rooms, activity monitoring in driving simulators and interviews inside parked automobiles (see section 2.7.2).
- Lack of comparability between previous studies involving collaboration with drivers due to major differences in the research focus. This leads to the need for further investigation towards a unified methodology to collaborate with drivers and to measure innovation (see section 2.6.2).
- Elements such as study design, protocol and results tend to be highly dependent on the selected study environment. This led to the need for further investigations of the equipment and collaboration methods required for this specific research (see section 2.5.3).

- Previous studies strongly focused on driving simulators. Driving simulators have been widely criticised for their capacity of not fully recreating the stimuli that users perceive in real driving conditions (Winter, Leeuwen, and Happee, 2012). Therefore, further investigations are recommended to review whether results collected in simulated conditions can be inferred to real driving conditions (see section 2.5.1).
- The importance of investigation of multiple cognitive and affective processes to estimate the effects that interacting remotely with a designer may have on automobile drivers (see section 2.5.1).

On the other hand, in order to address an investigation of the implementation of real-time remote collaboration with automobile users while they were driving and to answer the research questions defined in Chapter 1, the aforementioned observations were considered. Further, the requirements defined for this research were the following: (1) Definition of minimum requirements in terms of communication hardware and channel to allow designers and drivers for real-time remote collaboration. (2) Early-stage testing in a driving simulator, followed by a validation stage in real driving conditions. (3) Select a collaboration method which does not require drivers to use any office materials nor to glimpse away from the road for more than one second for road safety reasons. These decisions were made according to suggestions found in previous literature (Weber, 2017; Gkatzidou, Giacomin, and Skrypchuk, 2016; Bhise, 2012).

Lastly, based on the requirements defined for this research and the findings of the literature review, the co-design method selected to guide the interaction between designers and automobile drivers was Contextual Inquiry, which was considered as a form of a within-context semi-structured interview. In the next chapter, it is presented the methodology followed to conduct this research.

3. Methodology

3.1 Design Philosophies

As described in section 2.7.1, the Oxford English Dictionary defines ‘design’ as “the act of producing a plan or drawing of something before it is made”. Traditionally, the term ‘design’ has been used to refer to the abstract conception or actual plans for the development of artefacts or processes (Krippendorff, 1989). Specifically, typical uses of the term ‘design’ as a noun have been argued to suggest concepts such as a plan, drawing or sketch, whereas the use of design in its verb form is frequently associated with the definition of elements which describe something (Giacomin, 2014). Thus, the concept of design as a method to understand how things can be described and developed has been the subject of many studies (Brown, 2009; Brown, 2008).

Recent literature suggested that research conducted within the world of design may be classified into three major movements (Giacomin, 2014). These major movements are technology-driven design, human-centred design and sustainable design. In turn, these alternatives were characterised by their core discourses, which respectively focus on technical novelty, human meaning or planetary impact. Despite operating within the same regulatory, economic and contextual constraints, they often lead to distinguishably different results (Ceschin and Gaziulusoy, 2016; Giacomin, 2015; Giacomin 2014).

In the automotive industry, carmakers traditionally adopted a technology-driven design approach for the development of new models (Jaafarnia and Bass, 2011). As described in section 1.1, automotive companies tipically focused on the development of a wide range of technical characteristics which ranged from elements such as steam-powered engines to autonomous driving features. However, researchers working in the automotive industry are increasingly incorporating human-centred (Seat, 2017; Volkswagen, 2017) and sustainable perspectives to the design process (Audi, 2017; Porsche, 2017). These approaches tend to prioritise concepts such as customer experience, user behaviour or automobile efficiency (Sun et al. 2020; Cha, 2019; Ceschin and Gaziulusoy, 2016 Peters, 2013; Tullis and Albert, 2013).

As discussed in Chapter 1, this research took the view that automotive designers could conduct customer interviews while drivers were inside automobiles real-time, in real-life contexts for the analysis and improvement of customer experience. Therefore, a human-centred approach was adopted. Accordingly, the following sections describe in more depth the characteristics of the human-centred design approach, as well as some of the methods most frequently used.

3.2 Human-Centred Design Approach

Human-Centred Design (HCD) has its roots in fields such as human factors or ergonomics, and it can be defined as an approach for the development of artefacts or processes which aims to maximise usefulness by focusing on their users, needs and requirements (IOS, 2019; Brown, 2009; Brown, 2008). To that end, this approach assumes that artefacts or processes under development have predetermined functions and in turn, those functionalities can be improved by following one or more usage patterns (Degani, 2004). According to the International Organization for Standardisation (2019) in their ISO 9241-210:2019, human-centred design can be characterised by six core principles. These principles are (1) the design is based upon an explicit understanding of users, tasks and environments, (2) users are involved throughout design and development, (3) the design is driven and refined by user-centred evaluation, (4) the process is iterative, (5) the design addresses the whole user experience, and lastly (6) the design team includes multidisciplinary skills and perspectives.

Currently, HCD is considered a field of expertise of its own, which involves dedicated conferences (i.e. DIS 2020) and the involvement of professionals such as user experience specialists, usability researchers and specialised designers (Bijl-Brouwer and Dorst, 2017). In practice, designers who adopt an HCD approach tend to focus on the possible degrees of interactivity, exploration and learning associated with the artefact or process under development. In turn, products and processes developed through an HCD approach are frequently labelled as ‘intuitive’ and ‘useful’ (IOS, 2019; Giacomin, 2014).

This consideration of HCD as a field of expertise is the result of an evolutionary process which lasted for decades. Traditionally, design practices were based on a reduced number of activities which included iterative design, prototyping or the inclusion of multidisciplinary collaboration (see section 2.7.1 for further detail). With the appearance of participatory design practices in Scandinavia during the 1970s, the incorporation of customer insights to the design process has increasingly gained relevance for the achievement of innovation (Sanders and Stappers, 2008; Cross, 1971). Subsequently, professionals in innovative companies have increasingly aimed to understand their customers by exploring their goals, concerns, aspirations and motives (Giacomin, 2014). Such evolution in the design perspective has gradually led researchers to argue that testing products in a lab do not always provide enough valid insights which allow for estimation of actual use in situ (Bijl-Brouwer and Dorst, 2017). Therefore, researchers started implementing contextual design techniques, which allowed for the study of taxonomy and ontology of interactions occurring between people and their environments (Giacomin, 2014). This approach has been criticized for not providing straightforward answers to designers, even though the data typically collected is considered rich by the literature (Bijl-Brouwer and Dorst, 2017). To be specific, various scholars argued that there is a 'gap' between design practice and user research (Norman, 2010; Wixon, 2003). To close this gap, three working strategies were developed and refined to currently compose the heart of HCD practices. Initially, designers explored descriptions of users and their interactions with alternative design proposals (Spinuzzi, 2005). Subsequently, users were invited to adopt a designer perspective through participatory design workshops (Sanders and Stappers, 2008). More recently, designers were invited to adopt a user perspective through empathy stimulating techniques such as experience prototypes, role-playing or storytelling (IDEO, 2015).

All these practices are currently implemented in alternative industries as described in section 1.5 (Bijl-Brouwer and Dorst, 2017; Sanders and Stappers, 2012). Regarding automotive design, HCD practices have gained popularity over the past decade and as its use has mostly focused on customer interviews inside automobiles. In order to provide wider information in regarding the possible manners in which the HCD approach can be implemented, the following section discusses HCD methods which are frequently used, as well as the procedure which guided the research described in this thesis.

3.3 Human-Centred Design Methods

As described in the previous section, HCD refers to the design approach which aims to maximise the usefulness of products or processes by focusing on their users, needs and requirements. To that end, professionals adopting an HCD perspective tended to conduct studies which analyse the relevance of the context where the product or process under development is used, and those practices frequently involve collaboration between designers and users.

According to the literature, researchers have used a wide spectrum of HCD methods for the development of useful products or processes (Rosenzweig, 2015; Tullis and Albert, 2013; Martin and Hanington, 2012; Maguire, 2001). These methods ranged from usability cost-benefit analyses to experience interviews conducted with existing users. Maguire (2001) provided a classification in which HCD methods were classified depending on their aims within the design process (Table 9).

Aim	Examples of HCD Methods	
Planning the Design Process	• Usability planning and scoping	• Usability cost-benefit analysis
Understanding the Context of Use	• Surveys of existing users • Field studies	• Diaries • Task analysis
Defining User Requirements	• User requirements interviews • Focus groups	• Scenarios of use • Personas
Producing Designs and Prototypes	• Brainstorming • Card sorting games	• Software prototyping • Wizard-of-Oz prototyping
Conducting User-Based Evaluation	• Participatory evaluation • Controlled user testing	• Satisfaction evaluation • Post-experience interviews

TABLE 9: EXAMPLES OF HCD METHODS (MAGUIRE, 2001)

On the other hand, the focus of this research involved the analysis of possible constraints and benefits of implementing real-time remote contextual inquiry while automobile users were driving in order to collect user feedback and improvement ideas. As discussed in Chapter 1, contextual inquiry was defined as a form of customer interview which occurs in the environment where the customer uses a product, and the selection of this method was due to its possible benefits towards compensating limitations in the current automotive research practices (Giuliano, Germak, and Giacomin, 2017; Cha et al., 2015; Ramm et al., 2014). To be specific, recent literature highlighted the need for further studies inside automobiles to provide automotive designers with a greater insight into the experiences which drivers have inside automobiles for the development of innovative concepts (Milakis, Arem, and Wee, 2017; Gkatzidou, Giacomin, and Skrypchuk, 2016). This can be associated with a limited number of studies involving interviews, observation or diaries while participants were driving (Olsson and Jansson, 2005).

Despite recent studies involved interviewing while participants were inside an immobile automobile (Ramm, et al., 2014) or observation while participants were driving (Weber et al., 2018), these studies did not aim to grasp how drivers experienced automobiles, neither to collect innovative concepts for the improvement of the automobile. Thus, due to a lack of literature addressing this challenge, the research method selected to collect such information was real-time remote contextual inquiry, and the research methods used in this research were selected to define some 'minimum' requirements for the implementation of real-time remote contextual inquiry in automobiles and to explore its possible benefits and consequences.

As described in section 2.7.2, recent literature addressing collaboration with customers in real-life contexts highlighted that for the implementation of such collaboration, it was required to define equipment requirements to support the collaboration (Westerlund, Leminen, and Habib, 2018). Therefore, the definition of communication hardware requirements and communication channel requirements was prioritised. To define those requirements, two independent studies were sequentially conducted. The first of these studies addressed the definition of communication hardware requirements and the second of these studies addressed the definition of communication channel requirements.

Once the first two studies were conducted and the requirements in terms of communication hardware and channel were defined, two more studies were designed and conducted to (1) explore possible benefits of implementing real-time remote contextual inquiry for the collection of ethnographic data and improvement ideas, and (2) test the decisions made across the research under realistic driving conditions through their consequences towards drivers' emotions.

Lastly, it is worth noting that to increase the robustness of the research outcomes, this investigation adopted a triangulation approach within-studies and across-studies. Triangulation refers to the practice of using multiple sources of data or multiple approaches for its analysis to provide an increased understanding of the phenomenon under investigation. This is a frequent practice among HCD researchers (Cha, 2019; Weber, 2017; Ramm, 2016) and according to Flick (2018), it can be implemented at several phases of a research project. Some examples of implementations include when two or more sub-projects are pursued and their results are used as complementary information, compared or linked, or when several qualitative and quantitative approaches are used to analyse the same data. Thus, it was decided to include both quantitative and qualitative data in the 4 studies, and the results of each study were considered for the design of the following. Further detail in regards to both quantitative and qualitative data collection, as well as the analysis methods applied for each study, is included respectively in Chapters 4, 5, 6 and 7.

3.4 Threats to Validity

The aforementioned decisions which were taken to conduct this research, as well as the specific research area framing this investigation involve certain limitations which are described in the following:

A first step towards interviewing customers while they are driving an automobile. As mentioned in the previous sections, there is a limited body of literature in which automobile drivers are interviewed for feedback and improvement suggestions while driving. Therefore, further investigations are needed in order to explore possible consequences and benefits offered by this practice.

Unstandardized methods to measure innovation. As discussed in section 2.7.3, researchers have not reached a consensus to define innovation yet. Previous literature refers to innovation interchangeably with creativity and this leads to a lack of agreement regarding its constructs and measurement techniques. This research followed a heuristic approach to answer the research questions. However, further investigations are needed in order to standardize a definition of innovation as well as its measurement in collaborative studies.

Sample size and diversity. The sample sizes for the conducted studies ranged between 24 and 34 in accordance with suggestions found in the literature (Lazar, Feng, and Hochheiser, 2017). However, larger sample sizes can sometimes increase the variety and reliability of the results. Furthermore, participant recruitment processes took place in the area surrounding Brunel University (London, United Kingdom). This might have led the samples to be of limited cultural diversity. Thus, even though the demographics were similar to those typically used for such type of studies, future studies are recommended to include larger and more culturally diverse samples.

Driving simulators. These technologies have been criticised for their capacity of not fully recreating the stimuli that a driver can perceive in real driving conditions (Lucas et al., 2020; Winter, Leeuwen, and Happee, 2012; Blana, 1996). For instance, researchers advocated that the use of driving simulators involves higher levels of mental workload than operating real automobiles and on the other hand, researchers argued that the mental workload depends on the secondary activities performed during the tests instead of depending on the driving task itself (Blana, 1996). This leads to questioning whether the results collected in driving simulators can be applicable to the real world. Blana (1996) argued that the applicability of such type of results strongly depends on the specific nature of the project. Therefore, the results obtained in a driving simulator should be tested to be collectable under real-driving conditions.

Length of studies. In order to secure participants safety and according to Brunel University ethics restrictions, the 4 studies were restricted in terms of time (i.e. to reduce the risk of simulator sickness or drowsiness in the real car). This might have led to collect data biased by the limited time available for each test. Future research should include longer studies in order to explore further behaviours in both driving simulator and real car as long as the participants' safety could be guaranteed.

Lastly, it is worth noting that limitations specific to each of the studies conducted are discussed in the individual study chapters.

3.5 Summary of Methodology

As described in the previous sections, an investigation was conducted in order to explore the possibility and benefits of implementing real-time remote contextual inquiry sessions between automotive designers and automobile drivers while these are driving. To that end, it was followed a holistic approach in which two studies were conducted to explore automotive-specific requirements to implement real-time remote contextual inquiry with drivers, and two studies were conducted to evaluate the results of the implementation of real-time remote contextual inquiry under both simulated and real driving conditions. All these studies were sequentially conducted (Table 10).

	Study 1	Study 2	Study 3	Study 4
Study aim	Defining Communication Hardware requirements	Defining Communication Channel requirements	Exploring possible benefits of real-time remote contextual inquiry	Exploring possible consequences of real-time remote contextual inquiry
Study conditions	Driving simulator	Driving simulator	Driving simulator	Driving a real automobile
Data collection	Qualitative data Quantitative data Statistical tests	Qualitative data Quantitative data Statistical tests	Qualitative data Quantitative data Statistical tests	Qualitative data Quantitative data Statistical tests
Conclusions	Selection of communication hardware to support real-time remote contextual inquiry	Selection of communication channel to support real-time remote contextual inquiry	Analysing outcomes of real-time remote contextual inquiry in simulated driving conditions	Analysing outcomes of real-time remote contextual inquiry and observation in real driving conditions

TABLE 10: SUMMARY OF THE METHODOLOGY USED TO CONDUCT THE RESEARCH

4. Study 1: Defining Communication Hardware Requirements for Real-Time Remote Collaboration with Drivers

4.1 Introduction

Chapters 1, 2 and 3 described the nature and the potential usefulness of a communication channel between automobile drivers and designers, as well as some of the concepts to be explored for the implementation of on-road remote contextual inquiry sessions with the proposed approach to conduct such exploration. The first of these issues involved the selection of the *communication hardware* required to support these sessions (see sections 1.7 and 3.5 for further detail). Communication hardware refers in this context to any piece of equipment capable of supporting remote communication between collaborators. This chapter discusses a study which aimed to explore which communication hardware can be installed inside the automobile for remote communication between automotive designers and automobile drivers.

Among the computer-mediated communication tools reviewed in section 2.5.3, the alternatives which could support on-road real-time remote collaboration for research testing were the voice conference call and the video conference call. This was due to their capacity to communicating users in different locations real-time, including a voice-based channel which allowed driver to maintain the sight on the road while interacting with the designer. In turn, the communication hardware considered to implement these approaches within an automobile included an on-board screen, an on-board microphone, and an on-board speaker. Thus, this communication hardware was installed within the automobile as part of the dashboard and subsequently tested under different study conditions (Figure 18). It is worth noting that the implementation of equipment tailored to support video conference calls within automobiles may be subject of legal restrictions depending on the geographical context in which the automobile is commercialised (GOV, 2019). Therefore, the video conference call was only analysed for research purposes in this document. The location of the communication hardware inside the automobile was selected in order to reduce bias associated with unfamiliarity with its location (GPO, 2011).

FIGURE 18: SAMPLE OF DASHBOARD CONTROLS AND DISPLAYS (MIKESPHOTOS, 2020)

On the other hand, due to the dynamic nature of driving, respondents need to firstly focus on operating the automobile, which may lead them to ignore variables which would attract their attention in a safer, static environment (i.e. screen resolution, screen colour range, partner's intonation, body language, etc.). Cognitive Psychology suggests the division of the mental resources between primary, secondary and even tertiary tasks critically affects the performance on those activities (Lee, Lee, and Boyle, 2007; Posner and Boies, 1971). Therefore, in a context in which one of the collaborators is primary driving and participating in a conversation as a secondary task, the perception of different elements of the environment can vary according to cognitive affordances of the individual. These issues led to study the effects of the communication hardware on drivers' cognitive affordances such as perception, mental workload or performance (Datcu, Lukosch, and Lukosch, 2013; Ma and Kaber, 2006; Baren and IJsselstejin, 2004).

The experiment presented in the following sections aimed to explore how the characteristics of the communication hardware affected the drivers while they were operating an automobile and multitasking. The research question proposed for this experiment assumed that the characteristics of the communication hardware affected the driver while driving and multitasking and stated: *'Which apparatus can be installed and which specifications should they have?'*

4.2 Aim

As discussed in the previous section, a study was conducted to explore how the characteristics of the communication hardware affect the perception and performance of the driver, and to select which communication hardware to install inside the automobile to support real-time remote collaboration between automotive designers and automobile drivers.

Based on the findings of the literature (see section 2.5.3, Figure 10 for further detail), the selected technologies to support real-time remote interaction between designers and drivers were the voice conference call and the video conference call. In turn, the communication hardware that support these solutions included microphones, screens and speakers. Since the on-board microphone did not provide information to the drivers as much as the on-board screen or the on-board speaker, such device was decided to be excluded from this study. Moreover, due to the exploratory nature of this study towards the implementation of real-time remote contextual inquiry between automotive designers and automobile drivers, it was followed an inductive approach which aimed to analyse:

i. *Possible effects of the on-board screen on the driver*
ii. Possible effects of the on-board speaker on the driver

4.3 Methodology

Once the aims of the study were defined, and the characteristics of the communication hardware were selected, a 3x3 between-subjects experiment was designed and conducted. During such an experiment, participants were asked to drive and perform a sequence of tasks which required them to interact with a screen and a speaker. In turn, the independent variables studied in the experiment were screen size, screen resolution and speaker volume.

Due to the exploratory nature of this study, the range of screen sizes selected for the tests was composed by the maximum diagonal length for the most sold tablet models in 2017 (Anon., 2019) and the minimum diagonal length for the most sold smartphones in the same year (Anon, 2020). These values were respectively 10.1 inches and 4.3 inches. To provide a greater perspective of possible screen size effects on drivers, it was decided to include an additional screen size with a value between 10.1” and 4.3”, being selected the diagonal of 7”. Once the screen diagonals were selected, the lengths and widths in inches were defined based on market availability of tablets with those screen diagonal sizes. Thus, the screen sizes selected for this study were 7.8” x 5.8” (measuring 10.1” its diagonal), 5.6” x 4.2” (measuring 7” its diagonal), and 4” x 3” ” (measuring 4.3” its diagonal).

Similarly to the case of the screen size, in order to mould a noticeable difference between conditions, two screen resolutions and frame rates were tested. These resolutions and frame rates were selected below 1080p to reduce possible bandwidth requirements in a hypothetical real-time remote collaboration. Thus, the selected values were 854 x 480 pixels and 320 x 180 pixels, with the first number being the width of the frame and the second number the height.

Lastly, recent literature suggested that noise present inside an automobile may range between 60dB and 80dB (Sliggers, 2015). Therefore, to provide a general perspective of possible effects of the speaker volume on drivers, three volumes were tested, being their values 61 dB, 68 dB, and 77 dB. Sound volume was measured at driver’s left ear to match previous research practices (Sliggers, 2015).

In summary, the three independent variables studied with the experiment are presented next: (1) screen size with three study conditions – (i) 7.8” x 5.8” (ii) 5.6” x 4.2” or (iii) 4” x 3”, the (2) screen resolution with two study conditions – (i) 854 x 480 pixels or (ii) 320 x 180 pixels and lastly (3) the sound volume with three study conditions (i) 77dB, (ii) 68dB and (iii) 61dB (Table 11).

Screen Options	Size (inches)	Resolution (pixels)
1	7.8 x 5.8	854 x 480
2	5.6 x 4.2	
3	4 x 3	320 x 180

Speaker Options	Volume (dB)
1	77
2	68
3	61

TABLE 11: INDEPENDENT VARIABLES AND STUDY CONDITIONS STUDIED FOR THE CHARACTERISTICS OF THE COMMUNICATION HARDWARE

4.3.1 Measurement instruments

As seen in the previous sections, the screen size, screen resolution and speaker volume sometimes affect the cognitive processes of their drivers, depending partially on their characteristics and the conditions in which they are used. According to the literature, the methods most frequently used to collect information regarding the cognitive processes are experience questionnaires (Brooks and Hestnes, 2010) and objective instruments such as physiological measurement techniques or task performance (Sheykhfard and Haghighi, 2019). Among all the methods reviewed to determine the impact that the communication hardware has on the driver's perception and performance in section 2.5.2, three instruments which are frequently applied to measure user experience were selected:

The **Mental Workload** is one of the most frequent instruments used in cognitive psychology to collect data in regards to activity performance (see section 2.5.1 for further information). The study of the perceived mental effort, cognitive load or mental workload is typically addressed through physiological responses or post-task questionnaires. In automotive applications, mental workload (also referred to as cognitive load) is frequently used to estimate the difficulty of a given task (Jeon, 2015). In this experiment, the Subjective Mental Effort Scale was selected as the instrument for the workload evaluation due to its simplicity to answer and analyse (see Appendix F.1.1).

The **Perceived Media Quality** aims to evaluate the quality of experience based on the specific needs of a specific study and it is usually measured through Likert-scale questionnaires. This metric was selected in order to create a basic understanding of driver's perception of the screen characteristics. Among the options typically used to measure perceived media quality, there is a set of standardized instruments gathered by the International Telecommunications Union (ITU) that allow users to rate the quality they perceive in a media source. These standards include the time that these experiments should last, the recommended places to run these tests and the suggested questionnaires to use. Based on one of these methods called ITU-T P.910, a newly customised questionnaire was developed and used on the tests (see Appendix F.1.1). This instrument was selected for this study for being standardized.

Lastly, the **Error Rate** was selected to model the activity performance of the participants while driving for being one of the most extended metrics used in the automotive industry (Jeon, 2015). This metric was assessed quantitatively depending on the specific task types in order to reduce researcher bias. The error rate is a measurement technique that requires criteria to count when participants are acting erroneously. This metric was selected for being based on objective data. A more detailed explanation of the criteria is provided in the 'secondary tasks' part of the next section. A sample of the sheet used on the tests is attached to Appendix F.1.2.

4.3.2 Stimulus materials

During the study, all the participants were surrounded by a range of stimulus materials. This included a driving simulator, an on-board screen, an on-board speaker, and three different secondary tasks conducted while participants were operating the driving simulator:

Driving simulator. The equipment used to emulate the road was a driving simulator which consisted of a static, fixed basic, fully interactive simulator based on a 2006 Jaguar S-type full automobile body (Figure 19). The software used to run the simulations and was named "City Car Driving" and it was selected due to flexibility to recreate alternative environments and traffic conditions. Visual stimuli were provided by three projectors (Toshiba TDP-95) pointing to three screens 2.4m x 1.8m long which created a 105° horizontal and 45° vertical field of view from the cab of the automobile. The video was displayed using the maximum resolution of the projectors was 1024 x 768 pixels and 60 FPS. Regarding the sound stimuli, a Creative Inspire 5800 sound reproduction system composed of 8 speakers provided 72 W of power with a 40 to 20,000 Hz bandwidth for the simulations. The seat was set by 4 different volunteers and randomly selected who agreed with the best position.

FIGURE 19: PICTURES OF THE DRIVING SIMULATOR PROPOSED FOR STUDY 1

The software variables belonging to the simulator (i.e. traffic density, pedestrian density, etc.) were fixed for simplicity reasons in a medium level (50% in a scroll bar, 60% when 50% option was not available). The implementation of a remote collaborative dialogue between designer and automobile driver was expected to take place regardless of the context in which the driver was located, therefore the environments set to drive through included a highway, country road and city road (Giuliano, Germak, and Giacomin, 2017). The scenarios were paired with the tasks (video, speech and image) aiming to balance the expected required workload (Silva, 2014). Thereby, image task was asked to be performed through an urban scenario, the video task was performed while driving in a highway and the audio task was done while driving in a country road.

On-board screen. In order to evaluate the characteristics required for the on-board screen, it was decided to use a Samsung Galaxy Tab A 10.1 tablet. This pick was due to this model to allow multitasking and therefore, resizing the working windows. Thus, the three screen sizes could be evaluated only by using a single physical device.

On-board speaker. The device selected to reproduce the sounds required for the test was an "Anker Stereo Wireless Bluetooth 4.0 Speaker" model A3141 with an output capacity of 20W. The choice of the device was based on its capacity to be connected through either sound cables or Bluetooth and its power. Previous to each test, a sample speech was reproduced through the speaker while the simulator engine was enabled and the volume was adjusted with a calibrated sound level meter. Both the screen and the speaker were located covering the control panel for being a position familiar to all the drivers where the screen could not block the vision of the road and the speaker is not covered by any object disrupting the sound quality (Ferlazzo et al., 2008; Santangelo and Spence, 2008; Losier and Klein, 2004). Both screen and speaker were installed together in order to preserve the unity of source of presence facing future work.

Secondary tasks. Three alternative tasks were considered as secondary to driving in order to create a basic understanding in regards to how drivers perceive the equipment characteristics on the road. These tasks were selected in order to create situations in which the participants were required to retire their sight from the road sporadically for short periods of time (image task), for long periods of time (video task) or not retire their sight from the road during the test (audio task).

- Image task: The participants were asked to navigate through a scenario by using a static map shown on the screen (see Appendix G.1). Since the task was performed three times by each participant, three scenarios with the same difficulty (same city and number of junctions but sorted in a different order) were developed in order to reduce learning effects. For the calculation of the error rate, each time a participant took the wrong exit in a junction an error was noted and he/she was notified and requested to go back to the junction to repeat the choice.
- Video task: The participants were asked to watch a video 24 seconds long while driving and to count the number of times that a group of people passed a ball between them. Since the task was performed three times by each participant, three videos with similar difficulty (lengths of 26, 24 and 24 seconds and a number of passes of 13, 12 and 12) were reproduced (Figure 20). The videos shown were based on the experiment carried by Simons and Chabris (1999). The number of errors was considered as the difference between the correct solution and the answer provided by the participants after counting the number of passes in the video.
- Audio task: The participants were asked to listen to a recorded speech and to count the number of times that a specific word was pronounced in it (see Appendix G.1). The number of errors was considered as the difference between the correct solution and the number of words counted and reported by each participant.

FIGURE 20: FRAME OF ONE OF THE VIDEO SEQUENCES PROPOSED FOR THE VIDEO TASK

In summary, all the independent variables, levels and dependent variables used for the study described in this chapter are summarised in the following (Figure 21).

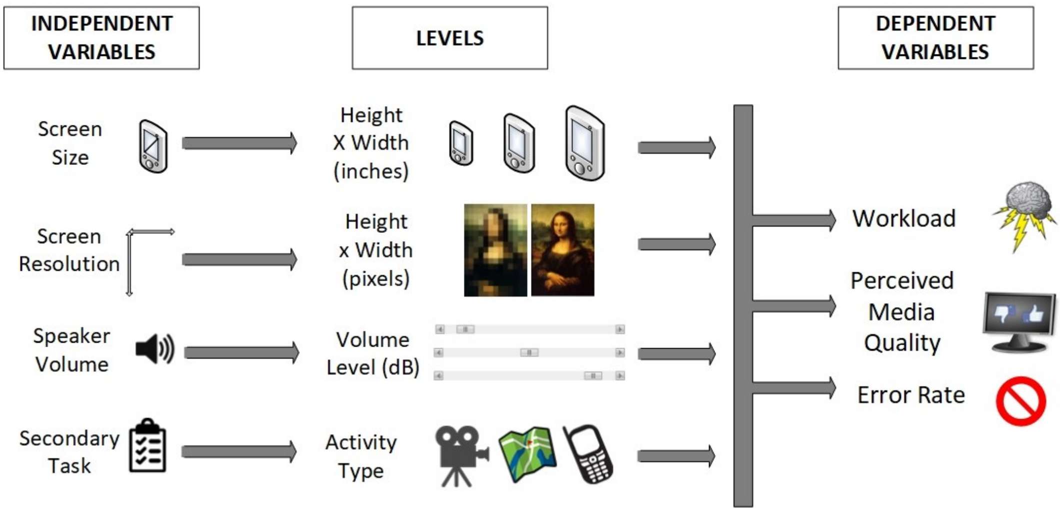


FIGURE 21: INDEPENDENT VARIABLES, LEVELS AND DEPENDENT VARIABLES USED FOR STUDY 1

4.3.3 Participants and recruitment

Based on the suggestions found in the literature, 20 samples was the minimum of participants required to conduct the test (Lazar, Feng, and Hochheiser, 2017; Francis, et al., 2010). Thus, a total of 24 participants (n = 24, 16 males and 8 females) ageing from 22 to 52 with a mean of 27 years old and a standard deviation of 6 years took place in the tests. Since this research aimed to remotely connect designers with automobile drivers regardless of their gender, ethnic background or age, the only condition for the participants to be recruited was holding an active and valid driving license.

On the other hand, all participants were informed about the goals of the experiment (see Appendix A) and asked to answer a screening questionnaire previous to start the tests in order to reduce the incidence of simulator sickness and a consent form agreeing to take part in the study (see Appendix B and Appendix D respectively). After the session, they were also asked to answer a health form to ensure the participants were not seriously affected by the simulator sickness (see Appendix C). All stages of the tests were performed under Brunel University's full ethics approval and in compliance with the pertinent ethics policy (see Appendix E).

4.3.4 Study protocol

To complete the study, the participants were randomly assigned to work under either high resolution (854 x 480 pixels) or low resolution (320 x 180 pixels) conditions. Then, each participant was asked to complete a total of nine tasks distributed following a Latin Square in order to cover all the study conditions for the screen size and speaker volume (Table 12).

	Screen size	**77 dB**		**68 dB**		**61 dB**		
1st Round	**7.8" x 5.8"**	Audio Task	**Evaluation**	Video Task	**Evaluation**	Image Task	**Evaluation**	**5 Minutes Break**
2nd Round	**5.6" x 4.2"**	Image Task		Audio Task		Video Task		
3rd Round	**4" x 3"**	Video Task		Image Task		Audio Task		

TABLE 12: PROCEDURE TO FOLLOW BY EVERY PARTICIPANT TO COMPLETE STUDY 1

After each task, the participants were asked to complete the SMEQ questionnaire for the perceived mental effort, the ITU-T P.910 questionnaire for the perceived media quality or to provide their answer for the audio task when required. These stages were labelled as "Evaluation" (Table 12). The error rate was noted by the researcher after the completion of every task (see Appendix F.1.1 for further information in regards to the questionnaires participants were asked to answer).

4.4 Results

As the participants concluded the study, their answers to the questionnaires and the notes of the researcher were digitalized onto an "IBM SPSS Statistics v24" file for analysis. The method used to analyse the data regarding the screen size and speaker volume was a repeated measures ANOVA test and its selection was due to these independent variables involving three study conditions and being tested by participants who were asked to repeatedly complete three tasks (i.e. video task, voice task and audio task). For the analysis of the data regarding the screen resolution, it was used a 2-tailed independent samples t-test. The selection of this method was due to the screen resolution presenting two possible values (i.e. 854 x 480 pixels and 320 x 180 pixels). T-values were expressed in this document with its absolute value to normalise the results of the statistical tests across the experimental chapters, independently of the structure of the data files under analysis. These decisions considered the suggestions made by Lazar, Feng, and Hochheiser (2017) regarding the selection of statistical tests.

When the significance of the repeated measures ANOVA test (calculated with $\alpha = 0.05$) was higher than 0.05, the null hypothesis was accepted, thus confirming that the differences between at least two of the three possible study conditions was NOT statistically significant and the null hypothesis was accepted. If the significance of such analysis was however lower than 0.05 (p-value ≤ 0.05), there was a difference between the variances in the population. Previous literature suggested that power analyses are "of little value" in exploratory studies (Jones, Carley, and Harrison, 2003). Therefore, such type of analysis was not included in this study. On the other hand and similarly to the case of the repeated measures ANOVA test, results collected from independent samples t-tests which provided significances higher than 0.05 led to accept the null hypothesis, whereas results which provided significances lower than 0.05 led to consider the differences between means of two samples as statistically significant.

Lastly, it was conducted a pairwise comparison to specify the study conditions which involved a statistically significant difference in the cases where the null hypothesis was rejected and which involved more than two study conditions for an independent variable (Hoaglin, 2003).

To provide an insight into the results of the statistical tests which were conducted, the acceptance and rejection of the null hypotheses which were proposed in this study were summarised (Table 13).

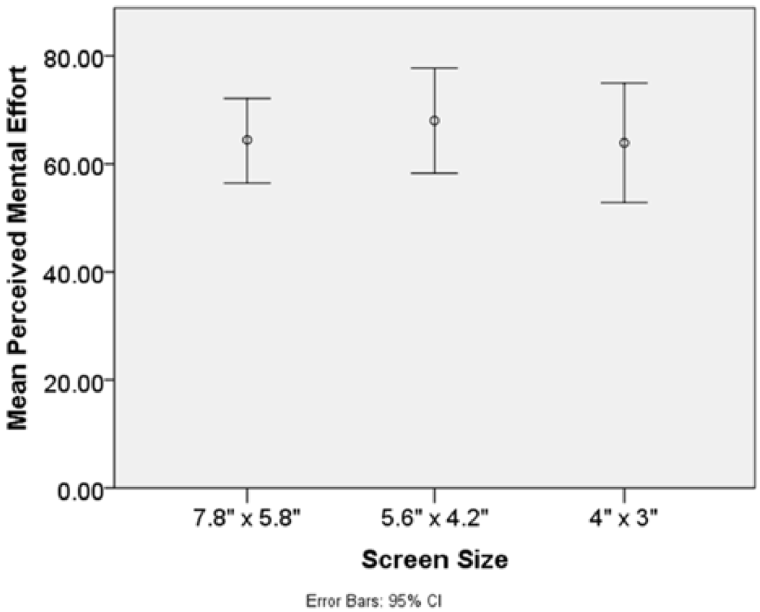
Independent Variable	Dependent Variable	Null Hypothesis
Screen Size	Perceived Mental Effort	Accepted
	Perceived Media Quality	**Rejected**
	Task Performance	Accepted
Screen Resolution	Perceived Mental Effort	**Rejected**
	Perceived Media Quality	**Rejected**
	Task Performance	Accepted
Speaker Volume	Perceived Mental Effort	**Rejected**
	Task Performance	Accepted

TABLE 13: SUMMARY OF THE HYPOTHESES VALIDATION FOR STUDY 1

4.4.1 The effects of the on-board screen on the driver

The data analysis in regards to the effects of the on-board screen on the driver was two-fold: (1) the effects of the screen size on the perceived mental effort, media quality and task performance (2) the effects of the screen resolution on the perceived mental effort, media quality and task performance.

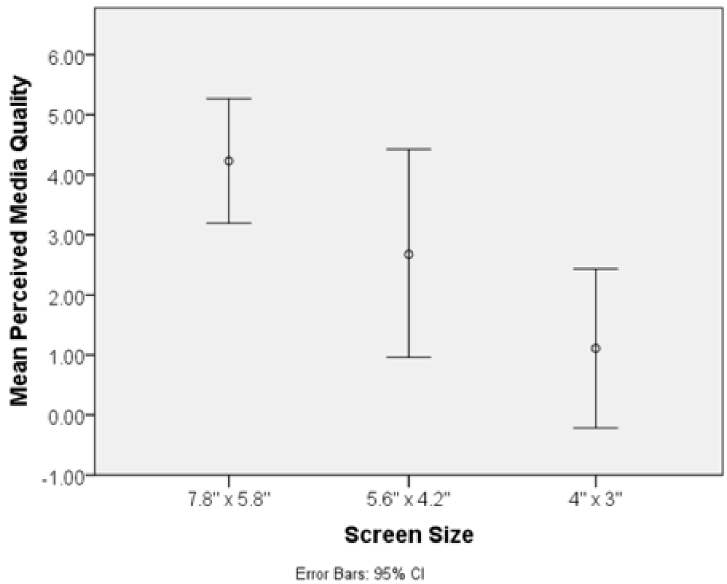
Regarding the effects of the screen size on the perceived mental effort of the driver, results did not show a statistically significant difference on the perceived mental effort when using different screen sizes between two or more study conditions ($F = 0.208$, p-value = 0.813 based on the repeated measures ANOVA test). Participants reported a statistically similar perceived required mental effort to perform the tasks regardless of the screen size they were using (Figure 22).



	Perceived Mental Effort	
Screen Size	**Mean**	**SD**
7.8” x 5.8”	64.620	25.524
5.6” x 4.2”	68.000	28.833
4” x 3”	63.900	32.665

FIGURE 22: MEANS AND STANDARD DEVIATIONS FOR PERCEIVED MENTAL EFFORT BASED ON SCREEN SIZE (N = 216 TASKS)

However, there was a significant difference on the perceived media quality when using different screen sizes between two or more study conditions (F = 13.511, p-value = 0.000 based on the repeated measures ANOVA test). A Pairwise comparison was conducted to determine the study conditions that presented different means and it reported a statistically significant difference between the perceived media quality in 7.8” x 5.8” and 4” x 3” screens (p = 0.000), and between 7.8” x 5.8” and 5.6” x 4.2” screen sizes (p = 0.004).



	Perceived Media Quality	
Screen Size	**Mean**	**SD**
7.8” x 5.8”	4.228	5.092
5.6” x 4.2”	2.674	4.587
4” x 3”	1.108	3.143

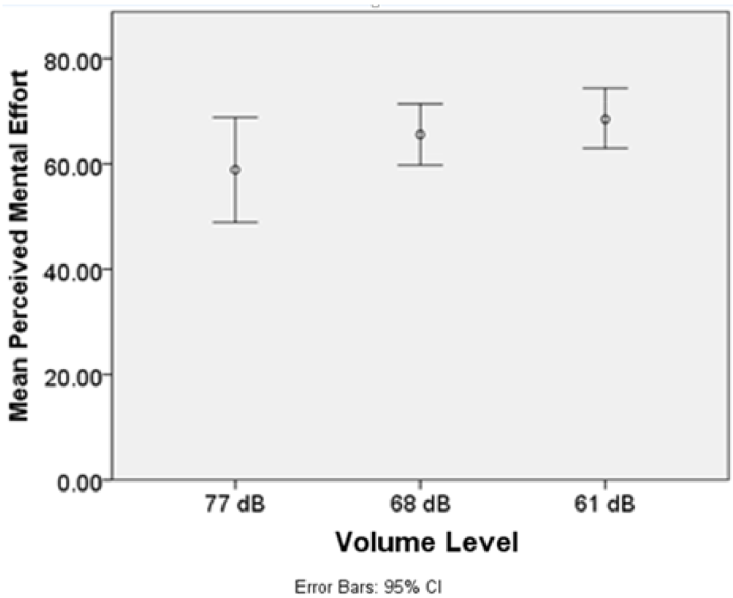
FIGURE 23: MEANS AND STANDARD DEVIATIONS FOR PERCEIVED MEDIA QUALITY BASED ON SCREEN SIZE (N = 216 TASKS)

Lastly, the effect of the screen size on the task performance was not statistically significant (F = 0.193, p-value = 0.825 based on the repeated measures ANOVA test). Participants completed the tasks with statistically similar error rates regardless of the screen size they were using.

On the other hand, the effect of the screen resolution on the perceived mental effort was statistically significant (obtaining t (214) = 2.337 and p = 0.020 in the independent samples t-test). Therefore, participants perceived the resolution of 854 x 480 pixels as more demanding in terms of mental effort (M = 68.880; SD = 26.355) than the resolution of 320 x 180 pixels (M = 60.623; SD = 27.750). Furthermore, there was a difference on the perceived media quality when using different screen resolutions (t (141) = 3.932, p = 0.000 based on the independent samples t-test). Therefore, participants perceived the resolution of 854 x 480 pixels to provide a higher quality media (M = 4.833; SD = 4.664) than the resolution of 320 x 180 pixels (M = 1.776; SD = 4.586). Lastly, the screen resolution did not significantly affect the task performance of the participants (t (214) = 0.076, p-value = 0.940 based on the independent samples t-test). Participants completed the tasks with statistically similar error rates regardless of the screen resolutions they were using.

4.4.2 The effects of the on-board speaker on the driver

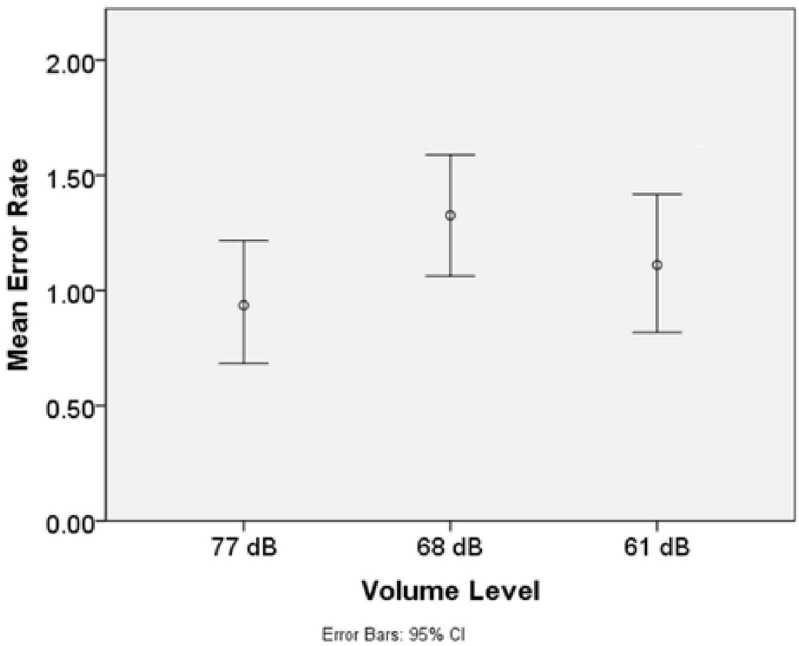
Lastly, it is presented the data analysis of the effects which the speaker volume had on driver's workload and performance. On the one hand, there was a statistically significant difference on the perceived mental effort when using different speaker volumes between two or more study conditions (F = 3.160, p-value = 0.049 based on the repeated measures ANOVA). Participants reported a statistically different perceived required mental effort to perform the tasks depending on the speaker volume they were using (Figure 24). A pairwise comparison revealed that such difference was located between the values of 61dB and 77dB (with a p-value equal to 0.017).



	Perceived Mental Effort	
Speaker Volume	**Mean**	**SD**
77 dB	58.875	29.444
68 dB	65.559	27.717
61 dB	68.472	22.670

FIGURE 24: MEANS AND STANDARD DEVIATIONS FOR PERCEIVED MENTAL EFFORT BASED ON SPEAKER VOLUME (N = 216 TASKS)

On the other hand, there was not any statistically significant difference on the error rate when using different speaker volumes between two or more study conditions (F = 2.298, p-value = 0.108 based on the repeated measures ANOVA test). Participants performed statistically similar during the tasks regardless of the speaker volume they were using (Figure 25).



	Error Rate	
Speaker Volume	**Mean**	**SD**
77 dB	0.806	1.009
68 dB	1.326	1.599
61 dB	1.111	1.430

FIGURE 25: MEANS AND STANDARD DEVIATIONS FOR ERROR RATE BASED ON SPEAKER VOLUME (N = 216 TASKS)

4.5 Discussion

The experiment shown in this chapter aimed to explore how automobile drivers were affected by some characteristics of communication hardware which can support remote collaboration with automotive designers. As described in the previous sections, in order to answer the research question ‘Which apparatus can be installed and which specifications should they have?’ it was decided to explore some possible effects of the screen and speaker on the drivers’ perceived mental effort, perceived media quality and error rate. Based on the results of the statistical analyses, three issues were highlighted in regards to the screen sizes, resolutions and speaker volumes which were studied: Firstly, the effects of the screen size on the driver’s perception of cognitive load and quality of the multimedia content; secondly, the effect of the screen resolution on the perceived mental effort and media quality; lastly, the effect of the sound volume on the perceived mental effort and the error rate.

Although recent literature supported a direct correlation between screen size and users’ workload (Hancock, Sawyer, and Stafford, 2015) none of the analyses showed the screen size having such an effect on automobile drivers for the screen sizes. The results showed that even though there was a tendency to reduce the perceived mental effort and as the screen size increased, differences were not statistically significant. This discrepancy with the previous literature can be due to the difference in the secondary tasks used for this study and the secondary tasks used by other authors. On the other hand, drivers perceived higher quality on the media displayed on larger screens than on smaller screens. This can be due to effects of the screen size on the time required to find patterns. Previous data suggested that larger screen sizes ease finding patterns at the same time that create difficulties to access to specific information (Hancock, Sawyer, and Stafford, 2015; Ni, Bowman, and Chen, 2006). In this case, the larger screen sizes led drivers to confuse perceived quality of media with perceived difficulty to find patterns in the media (i.e. number of passes made during a video clip).

On the other hand, results showed that the screen resolutions used for the tests affected significantly the perceived mental effort and media quality. This can be assigned to a larger amount of pixels requiring a greater amount of resources to be processed. These results aligned with previous research in which it was suggested that screen resolution affect the perceived mental effort of its drivers (Sakamoto et al., 2016; Ni, Bowman, and Chen, 2006). Regarding the media quality, the recent evolution of screens, desktop monitors and digital cameras towards an increase of the resolution suggests that higher numbers of pixels can be associated with higher quality of the product perceived by users (Pinnacor, 2003; w3schools, 2018). However, previous studies also suggested the perceived media quality to depend on the performed task when interacting with the screen (Lischke, et al., 2015). Thus, despite the results regarding the perceived media quality aligning with previous literature, it is worth noting that these were strongly dependent on the specific study conditions described in section 4.3.

Lastly, the relationship between the sound volume, the perceived mental effort and the task performance behaved similarly to the screen resolution. The results showed a tendency to reduce the perceived mental effort as the speaker volume was increased. Such effect was statistically significant and this aligned with previous literature in which it was suggested a relationship between noise, mental workload and task performance (Park and Lee, 1996). The reduction of the perceived mental effort experienced by drivers when they performed the audio task with 77dB can be associated with the volume of the speaker buffering environmental noise (i.e. automobile engine, road noise, etc.). Lastly, it is worth noting that drivers presented a tendency to tilt their head towards the speaker in order to improve their task performance during the audio tasks which involved 61dB and 68dB. However, the three volume conditions selected for this study were located in the range of amplitudes typically experienced in the interior of automobiles (Sliggers, 2015).

Summarising these three issues, larger screen sizes helped drivers to access more rapidly to the information of the on-board system and increased the sense of quality on the media sources. Higher resolutions involved greater amounts of pixels and therefore required a larger mental effort to be processed. The speaker volume is typically adjustable inside the automobiles and when the volume of a speech reproduced by the media equipment ranged between 61dB and 77 dB at driver's left ear, the drivers provided a similar level of understanding for all the investigated study conditions. Based on those comments and in terms of the research question, it appears reasonable that both on-board screen and speaker can be used to support real-time remote collaboration between designers and drivers. In terms of the characteristics of the screen, greater sizes with lower resolutions required lower levels of mental effort to use. In regards to the speaker, higher volumes required lower levels of mental effort to understand a verbal message.

4.6 Limitations

The experiment discussed in the previous sections was conducted in a driving simulator, which compared to a real-driving scenario included some disadvantages. To date, the complex nature of the driving environment cannot be accurately imitated due to physical, perceptual and behavioural fidelity limitations. According to the literature, these limitations sometimes cause participants lacking attention to the hazards and unrealistic driving behaviour, ultimately impacting the outcomes of the research (Bella, 2014).

This exploratory study aimed to create a basic understanding of the extent to which the characteristics of the communication hardware are perceived by the drivers on the road. To that end, three independent variables involving two or more study conditions each were evaluated through the use of three instruments. This approach generated a total of 216 samples from 24 participants. Although the sample size provides 'solid' results, the number of conditions in which the data was collected (i.e. each participant performed the audio task with the three volumes, but also with a different screen size each time) may have generated small inaccuracies in the statistical analyses. These inaccuracies can be avoided by designing simpler tests where a smaller amount of independent variables, study conditions and instruments are involved.

On the other hand, during the audio task, four participants (of a total sample size of n = 24) tilted their head towards the speaker to compensate for low sound volume. That helped them to reduce their errors on those tasks, affecting in turn the outcomes of such activity. Since the number of participants that followed that practice represents a small part of the total sample size such behaviour was noted by the researcher to be corrected in future research. The results of those participants were analysed against the rest of the sample with no significant evidence of a difference.

Lastly and in regards to the use of the error rate as a metric, it is worth noting that it was evaluated differently in each task and therefore, the data collected in different tasks is recommended to be compared separately. The data analysis did not include such results. The criteria to evaluate the error rate in the three different secondary tasks is included in 4.3.2 (stimulus materials), subsection ‘secondary tasks’. Furthermore, a preliminary analysis of the full data set in terms of error rate is included in Appendix G.2.

4.7 Conclusion

The motivation of the study presented in this chapter was to explore how drivers are affected by some characteristics of communication hardware when they are driving and interacting with such hardware. As part of this, a screen and a speaker were installed in a driving simulator in order to understand how the screen size, screen resolution and speaker volume affect the driver’s perceived mental effort, perceived media quality and performance when using them and driving at the same time.

Results suggested that among the alternatives tested in the study, larger screen sizes were perceived to display higher quality media sources. Screen resolutions with greater amounts of pixels were perceived as more demanding to use in terms of mental effort but were also associated with higher values for perceived media quality. The speaker volumes which were used in the study did not have a significant effect on a driver’s performance multitasking. However, participants reported a reduction in the perceived mental effort required to understand a recorded speech as the speaker volume increased. In summary, the participants were sensitive to variations in both the on-board screen characteristics and the speaker characteristics.

On top of those results, it is worth noting that while completing the video tasks, participants created five situations which led to an accident, suggesting that continuous attention to the screen should be avoided in future remote collaborative activities. Moreover, an additional analysis was conducted in order to explore whether the video task was more demanding than the image and the audio tasks in terms of mental effort. Such analysis is included in Appendix G.2 and confirmed that for the study conditions covered in this chapter, focusing the attention to a video while driving was reported as requiring significantly more mental effort than focusing the attention to a static image displayed on the screen or listening to a speaker.

In terms of the next steps to complete the research, these results supported the selection of voice conference call as the communication channel to hold the remote collaboration. Besides, literature suggesting that interaction with a virtual presence has an additional effect on the cognitive load of the driver aligned with these results (Ma and Kaber, 2006). However, video conference call offers more non-verbal information than the voice call (i.e. body language or facial expressions) (Salinäs, 2002). Non-verbal information has been argued to directly affect the presence in which a speaker is perceived (Newman, et al., 2016). Moreover, other researchers advocated the visual representation of a virtual presence to influence the users' feeling of closeness towards it (Nowak and Biocca, 2003). Therefore, the video conference call and voice conference call were subsequently tested to confirm, as a communication channel, which one of them can 'better' support the real-time collaborative dialogue between designers and automobile drivers.

5. Study 2: Defining Communication Channel Requirements for Real-Time Remote Collaboration with Drivers

5.1 Introduction

Chapters 1, 2 and 3 discussed the opportunity of creating a communication channel to connect automobile drivers with designers from a control room for real-time remote contextual inquiry sessions. For the implementation of such approach, four objectives were prioritised in section 1.7 to be included in the research. These objectives involved the selection of communication hardware and software to support remote collaboration, the design of the contents of the dialogue, and the study of the possible consequences of such remote collaboration for drivers' emotions. As part of the study for the equipment requirements, voice conference call and video conference call were prioritised as computer-mediated communication solutions for on-road real-time remote collaboration sessions (see section 2.5.3), and Chapter 4 discussed the selection of hardware based on the effect of its characteristics on the driver's perception of mental effort and media quality. However, the devices selected to support the remote collaboration are capable to support either video conference call or voice conference call, and the comparison between these options has not been addressed in this document yet. Furthermore, the communication channel supporting remote collaboration has been recently argued to significantly affect the dialogue (Irvine, Drew, and Sainsbury, 2012; Irvine, 2011; Fontes and O'Mahony, 2008). Therefore, voice conference call and video conference call were tested under on-road collaborative circumstances in order to determine which of them offers a 'better' alternative for the remote collaboration.

The main difference between the voice conference call and the video conference call relies on the inclusion of visual information by the second of these alternatives. Such visual information usually ranges from contextual cues to body language. Some examples of contextual cues that affect the outcomes of any verbal or non-verbal interaction are the perceptions of formality, warmth, distance, familiarity and privacy (Knapp, Hall, and Horgan, 2014). Body language on the other hand, involves gestures and facial expressions (referred as to non-verbal information onwards). Video-conference call solutions allow the exchange of such information. However, Chapter 4 suggested that those elements were sometimes ignored by the driver for the high levels of cognitive load reported when the participants had to focus their attention to a video while driving.

On the other hand, previous literature advanced the existence of a *virtual presence* on-board the automobile to potentially affect driver's steering performance (Ma and Kaber, 2006). The concept of *virtual presence* has been widely used in Human-Computer Interaction research and it is closely linked to remote interaction (Lombard, et al., 2015). The operative definition of *presence or virtual presence* for this document was "the experience of being engaged by the representations of a virtual world" (Jacobson, 2002) and a discussion of its constructs and applicability to this research was included in section 2.5.3. In turn, among all the options found in the literature, it was decided to include the social aspects of the virtual world for the selection of the communication channel. This decision was made due to the inherent interactive nature of both, real-time remote contextual inquiry, and the social aspects of virtual presence.

In summary, this chapter presents a study in which two computer-mediated communication technologies (voice conference call and video conference call) supported collaborative activities between automobile drivers and the research assistants. These two technologies were evaluated by the participants in terms of closeness feeling of presence they perceived with their interaction partner. The experiment described in the next sections took the assumption that the communication channel used to support the remote collaboration affects the outcomes of the collaboration, and therefore, it aimed to answer the research question: *'What is the optimal method to communicate automobile driver and designer for a real-time remote-collaborative interaction?'*

5.2 Aim

As seen in the previous section, this chapter aims to select an option within existing technologies and techniques to connect automobile and control room for remote collaboration, based on drivers' perception of virtual presence. The options proposed for evaluation to that end were the voice conference call and the video conference call.

According to the findings of the literature review, the perception of presence strongly relies on the information that users receive from the virtual world (Wirth, et al., 2007; Lee, 2004; Nowak and Biocca, 2003). In the interior of the automobile and especially while the user is driving, the virtual world was expected to offer the opportunity of exchanging information exclusively related to the dialogue (i.e. verbal information such as words and non-verbal information such as facial expression). However, Chapter 4 showed that due to cognitive affordances, drivers sometimes ignore details shown on the on-board screen in video-related activities. This might not be the case of the designers, who were expected to collaborate from an isolated room with reduced environmental distractions, and who therefore could be sensitive to such non-verbal information. Thus, this study aimed to investigate the following:

i. *The effects of the communication channel on the perception of virtual presence.*
ii. *The effects of driving an automobile on the perception of virtual presence*.

5.3 Methodology

After exploring the elements potentially affecting how remote collaborators perceive each other, selecting the most suitable communication channels to enable on-road real-time collaborators and defining the key aims of the study, it was conducted a 2x2 between-subjects. During the experiment, participants were grouped in couples, separated in different rooms and asked to accomplish a sequence of tasks while talking to each other through a computer-mediated communication tool. After completing the sequence of tasks, both participants were asked to respond to a presence questionnaire in regards to their experience during the test. The two independent variables studied with the experiment are presented next: (1) communication channel with two study conditions – (i) Voice conference call or (ii) Video conference call, and (2) role of the participant, with two study conditions too – (i) Collaborator or (ii) Driver.

5.3.1 Measurement instruments

As described in section 2.5.3, virtual presence perception has been typically studied through three alternative approaches. These approaches may respectively focus on how users perceive their presence towards the virtual world, how users perceive the virtual world, and how users perceive the interaction between themselves and the virtual world. Among these options, it was decided to focus on how users perceive the interaction between themselves and the virtual world, for being an alternative frequently used to evaluate the quality of interaction (Lombard, et al., 2015). This approach has been also referred to as the analysis of the social constructs of virtual presence (Lombard et al., 2015; Biocca, 2006). The instruments most frequently used to measure social constructs of virtual presence tend to consist of paper-and-pencil questionnaires (Baren and IJsselstejin, 2004). Accordingly, a questionnaire was selected to collect such data in this experiment. The selected questionnaire was proposed by some of the most referenced researchers in the area (Nowak and Biocca, 2003). This questionnaire was selected for focusing on the social constructs of virtual presence and the reputation of its authors. The social constructs of virtual presence covered by the questionnaire were represented by scales to assess Self-Presence, Co-Presence and Social Presence (see Appendix F.2). In turn, the definitions of these constructs are presented next:

The **self-reported co-presence** referred to the feeling of connection between two people and it was represented by a Likert-type scale which required the participant to evaluate his involvement in the interaction.

The perceived **other's co-presence** scale was also related to the feeling of connection between two people, it was represented by a Likert-type scale and additionally derived from a combination of the indicators for intimacy, involvement and immediacy.

Finally, the **social presence** was defined by the "perceived ability of the medium to connect people" and it was measured by a sliding scale questionnaire composed of 5 questions.

As described in section 2.5.1, the evaluation of presence perception has been addressed in previous literature from different perspectives (i.e. spatial presence, social presence, remote presence). Among those possible options, it was adopted a social presence perspective due to the interactive nature of the real-time contextual inquiry sessions which were aimed to investigate across the research. It is worth noting that that the original questionnaire proposed by Nowak and Biocca (2003) included scales for Telepresence, Co-presence (self and other's) and Social presence and that in this study, the scale for Telepresence was not included. This was due to such scale aiming to evaluate the level of immersion on a simulation, and that was not required in this study.

5.3.2 Stimulus Materials

As described in section 5.3, participants were grouped in couples, assigned a role and subsequently separated in different rooms. The roles were either driver or research collaborator, and depending the role assigned to each participant, they were allocated in the driving simulator or in a control room. Then, they were asked to accomplish a sequence of tasks while talking to their partner through a computer-mediated communication tool. The controlled elements affecting the participants' experience were the driving simulator, the communication channel, the assigned role for the test, and the tasks they were asked to complete.

Driving simulator. The driving simulator used for this study was the same described in section 4.3.2, including the Jaguar S-type body shell, a Toshiba TDP-T95 projection system, a Creative Inspire 5800 sound reproduction system, and "City Car Driving" as simulation software to support the activities for the tests. All the activities performed throughout the tests took place in a simulated urban scenario in order to increase the need for communication between participants due to the higher number of junctions such scenario offers compared to highways or country roads in this software. The software variables associated with the simulation (i.e. traffic density, light conditions, etc.) were fixed to the same values used for study 1 to ease triangulation between studies as described in section 3.3. Accordingly, those values were adjusted to 50% in the scroll bar and 60% when 50% option was not available.

Communication channels. The computer-mediated communication tools selected to support the conversation between participants were voice conference call and video conference call (which also included voice communication) for being two of the most extended CMC tools to support real-time collaboration activities between companies and for being applicable to automobiles while they are on the road (Kelsey and Amant, 2008).

Regarding the equipment the software selected to support the voice conference and video conference calls was Skype and it was installed in two terminals. On the one hand, inside the automobile, an iPhone SE fixed to the infotainment screen through a hands-free holder. On the other hand, in a separated room, an HP laptop with an Intel Core i-5 6200U 2.3GHz processor, 8GB RAM and 64-bit Operative System was used by the research collaborators to speak with the drivers.

Roles. Participants were randomly assigned a role and accordingly located in a specific room. Research collaborators were placed in a bare isolated control room while drivers were located at the driving simulator.

Tasks. This research explored the possibility of allowing automotive designers to collaborate with automobile drivers for the development of new automotive product and services. Therefore, it was decided to engage participants into remote collaboration in order to explore how they perceived each other while one of them was operating an automobile. The results of study 1 suggested that the involvement in secondary tasks sometimes may lead drivers to experience road accidents, especially when those tasks require interaction with videos shown in the on-board screen (see section 4.5). Therefore, the tasks to be performed during the collaboration were designed to actively engage both members of each couple into a dialogue during which they did not require continuous visual feedback from each other.

Furthermore, the implementation of real-time remote contextual inquiry sessions between automotive designers and automobile drivers was expected to address automotive-related themes by means of a creative dialogue (Gkatzidou, Giacomin, and Skrypchuk, 2016). Hence, the tasks selected for study 2 were also designed to encourage participants to discuss a driving experience, as well as to think creatively. Lastly, it is worth noting that in order to engage both participants of each couple into different collaborative conditions, the main researcher asked them to complete an increasingly difficult sequence of three tasks during the study. These activities were:

- Co-navigation with map: A map of the virtual city was installed inside the automobile, including a mark where the simulation started and the destination where the participant inside the simulator had to drive the automobile. Meanwhile, a copy of the map was provided to the research collaborator at the control room, and that participant was asked to guide the driver through a route drawn on the map. The fact that research collaborators did not have any vision of the road for being located in a separated room forced them to request visual feedback to the drivers in order to track the automobile through the map (see Appendix F.2). Participants had a maximum of 10 minutes to make the driver arrive at the destination point. If the driver did not reach the destination point in the limit of 10 minutes, the task was considered finished and the automobile was driven by the researcher to the starting point for the second task ('co-navigation without a map').

- Co-navigation without a map: The map of the city was removed from the simulator and a new version of the map with no route was provided to the research collaborator. For this activity, the participant at the control room had only information about the starting point and the destination and was free to create any route to help the driver arrive at the destination in a maximum of ten minutes (see Appendix F.2). If the driver did not reach the destination point in the limit of 10 minutes, the task was considered finished and the automobile was driven by the researcher to the starting point for the third task ('riddle resolution').
- Riddle resolution: For the accomplishment of the last activity the participants had to resolve three question-answer type riddles in less than ten minutes while the driver was steering the driving simulator. The questions were provided to the research collaborator in a paper sheet, so he could read them to the driver and take notes before they agreed on a definitive answer (see Appendix F.2 for the questions from Sangiorgio, 2018).

All the participants were asked to complete these three tasks in the same order they are presented in the previous three paragraphs. Moreover, the three tasks were conducted across the same simulation map (see Appendix F.2 for further detail of the map).

5.3.3 Participants and recruitment

Based on the suggestions found in the literature, 20 samples was considered as the minimum of participants required to conduct the test (Lazar, Feng, and Hochheiser, 2017; Francis, et al., 2010). Therefore, a total of 24 participants (n = 24) took part in the study, including 12 research collaborators and 12 drivers (16 male and 8 female randomly assigned to the roles). Then, every research collaborator was assigned a driver and one of the two possible study conditions: voice conference call or video conference call. Thus, 6 research collaborators and

6 drivers completed the test under voice conference call conditions and 6 research collaborators and 6 drivers completed the test under video conference call conditions. The sample had an average age of 23 (SD = 3) with a range of 19-35 years old.

The selection of participants, as well as all stages of the tests, were performed under Brunel University's full ethics approval and in compliance with the pertinent ethics policy (see Appendix E). As part of the process, participants who were assigned the role of the driver completed a consent form and pre-test questionnaire to check whether they had any special health condition which could potentially provoke them to suffer any simulator sickness. Those who reported any of the specific condition agreed with Brunel Ethics Committee (see Appendix B) were reassigned the role of the research collaborator. After the session participants who were assigned to operate the driving simulator were also asked to complete a form to ensure they were not seriously affected by the simulator (see Appendix C). On the other hand, participants who were allocated to the control room as research collaborators only had to complete a consent form. All the participants were informed about the goals of the experiment and encouraged to ask any question they might have previous to the study and asked to complete a form in which they agreed to take part in the study (see Appendix A and Appendix D respectively).

5.3.4 Study protocol

In order to simulate a remote collaboration between designer and driver, participants were asked collaborate as a team. Subsequently, both participants composing each couple received instructions and a communication channel either voice conference call or video conference call was assigned to them. Then, they were allocated in their respective locations, which were a separated room (also called control room) for the research collaborator and the driving simulator for the driver, and the communication channel connecting them started.

To complete the study, participants were asked to complete the three tasks previously described in a maximum length of 30 minutes in order to reduce the risk of simulator fatigue (Winter, Leeuwen, and Happee, 2012). The average time for the accomplishment of the activities separated was 8.5 minutes with a total length for the whole study of 25.5 minutes.

Between activities, the participants were offered to have a break of five minutes in order to reduce the incidence of simulator sickness and after the last activity, they both had to answer a questionnaire including measures of co-presence and social presence (Table 14). Appendix F.2 includes a sample of the questionnaire which was used in this study.

	Task 1		**Task 2**		**Task 3**	
Activity	Co-navigation	**5 Minutes Break**	Co-navigation	**5 Minutes Break**	Riddle resolution	**Questionnaire**
Route requirements	Predefined route		Predefined route		Free drive	
Navigation Resources	Map in car: **Yes** Map in control room: **Yes**		Map in car: **No** Map in control room: **Yes**		N/A	

TABLE 14: PROCEDURE TO FOLLOW BY EVERY COUPLE TO COMPLETE STUDY 2

5.4 Results

Once every couple of participants completed the study, they were provided of a chocolate bar as a gesture of appreciation for their participation, and their answers were digitalized onto a “SPSS Statistics” file for analysis.

Regarding the analysis of the data, empirical studies suggested that Likert-type scales can be analysed through both parametric and non-parametric tests (Sullivan, et al., 2013). Since the measurement instruments selected to assess presence were previously validated, the procedure followed to conduct the data analysis followed the guidelines described by the authors of the questionnaire (Nowak and Biocca, 2003). To that end, it was performed a coding was on the answers to the questionnaire. Thus, the values from the Likert-scale were assigned values from 0 to 5 where 0 represented strongly disagree/low presence feeling and 5 represented strongly agree/high presence feeling. Means were calculated for each one of the roles and communication channels (Figure 26). For the investigation of the proposed study aims, which were described in section 5.3.1, it was conducted a visual inspection on Figure 26, followed by 2-tailed independent samples t-tests.

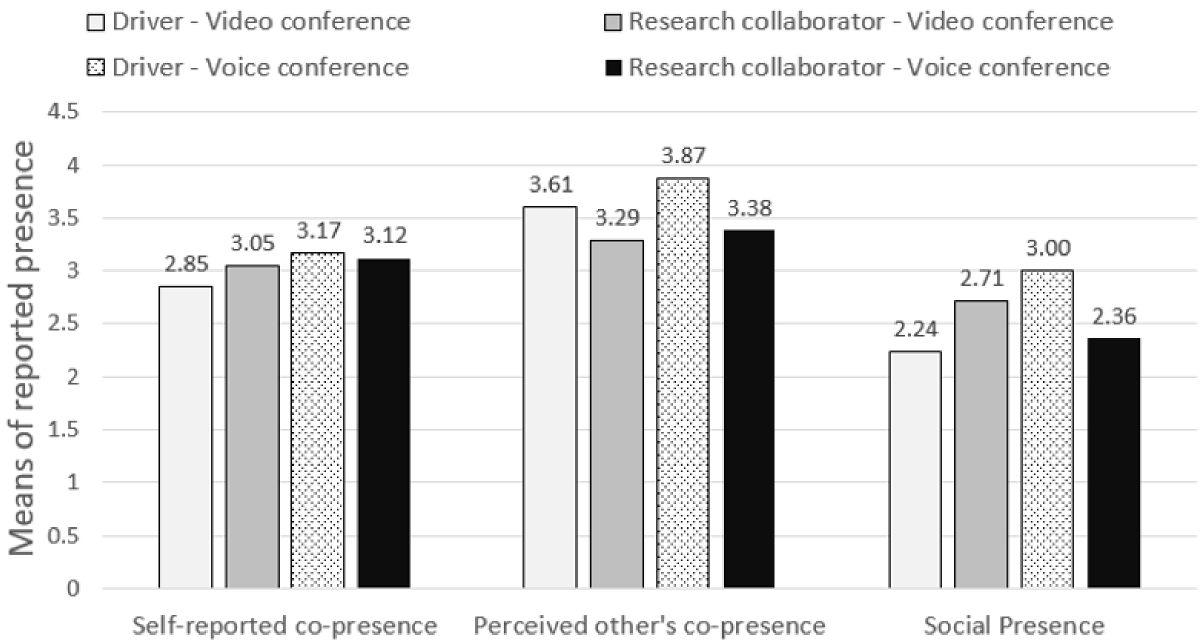


FIGURE 26: MEANS OF REPORTED PRESENCE BASED ON ROLE AND COMMUNICATION CHANNEL (N = 6 FOR EACH BAR)

These statistical tests were selected according to the suggestions made by Lazar et al. (2017) to analyse quantitative data when a study aims to find differences between two study conditions. In this case, the data was the presence perceived while collaborating, and four study conditions were defined and subsequently paired for separate analysis. The pairs of study conditions were the communication channel, being the possibilities voice or video conference call, and the role adopted by the participants during the study, being the possibilities driver or research collaborator. The approach followed to determine two samples were statistically different was the same applied for the data analysis of Chapter 4 and described in section 4.4. Since all the null hypotheses were accepted, power analyses were not conducted. To provide an insight into the results of this study, the outcomes of the independent samples t-tests were summarised (Table 15).

Independent Variable	Dependent Variable	Null Hypothesis
Communication Channel	Self-reported co-presence	Accepted
	Perceived other’s co-presence	Accepted
	Social presence	Accepted
Participant Role	Self-reported co-presence	Accepted
	Perceived other’s co-presence	Accepted
	Social presence	Accepted

TABLE 15: SUMMARY OF THE HYPOTHESES VALIDATION FOR STUDY 2

5.4.1 Effect of the communication channel on presence perception

Regarding the importance of the communication channel and in turn, the non-verbal information that computer-mediated communication solutions offer to both collaborators, two issues were observed:

Firstly, the effect of the communication channel on the self-reported co-presence was not significant: t (118) = 0.988, p = 0.325. Participants did not report themselves as less involved in the interaction when using voice conference (M = 3.16; SD= 0.3) than when using video conference (M = 2.96; SD = 0.33). Moreover, neither the effect of the communication channel on the other's perceived co-presence was significant: t (118) = 1.681, p = 0.095. Participants did not perceive less other's co-presence when using voice conference (M = 3.68; SD = 0.66) than when using video conference, (M = 3.48; SD = 0.45). Indeed, participants who used the voice conference as communication channel reported higher values on both self and others' co-presence than those who used video conference.

Secondly, the effect of the communication channel on the social presence was not significant: t (118) = 0.609, p = 0.544. Therefore, participants did not perceive less social presence when collaborating through voice conference (M = 2.72; SD = 0. 51) than when collaborating through video conference (M = 2.61; SD = 0.84); same as regarding to the reported co-presence.

5.4.2 Effect of driving on presence perception

Alternatively, in regards to the effects of driving on how collaboration partners perceived the each other, two observations were highlighted:

The effect of collaborating from the control room instead of driving on the self-reported co-presence was not significant: t (118) = 0.448, p = 0.655. Participants felt themselves as involved in the conversation as their research collaborators (M = 3.09; SD = 0.25) than when they were the driver (M = 3.03; SD = 0.39). Furthermore, the effect of the role on the other's co-presence perception was not significant either: t (118) = 1.898 and p = 0.060, which means that research collaborators (M = 3.40; SD = 0.66) did not perceive differently the other's co-presence than drivers (M = 3.76; SD = 0.40).

Moreover, the effect of collaborating from the control room instead of being driving on the social presence was not significant either: $t_{(118)} = 0.513$, $p = 0.609$. Research collaborators (M = 2.60; SD = 0.59) did not perceive significantly less social presence than drivers (M = 2.72; SD = 0.78).

5.5 Discussion

From the results obtained, various theoretical issues regarding mediated interactions with automobile users were raised. Firstly, despite the results not being statistically significant, drivers reported higher values for the three categories of presence when using voice conference than when using video conference as a communication channel. This fact can be associated with automobile drivers being more familiar with using a hands-free device than using video calls. Thus, the use of only voice call led drivers to feel naturally closer to their respective research collaborator under the experimental conditions. Previous literature argued that the feeling of 'naturalness' aligns with trustworthiness, which is a concept frequently associated with successful collaborations (Challender, Farrell, and McDermott, 2019; Ramm, 2016; Chua, Morris, and Mor, 2012; Nevejan, 2009). Moreover, the inclusion of visual cues at the automobile's terminal introduced a source of distractions on top of those inherent to driving. This affected the cognitive resources the drivers used to perceive a virtual presence while they were operating the driving simulator.

On the other hand, all the participants were asked two yes-no type questions after the test to complete the information of the questionnaires in the interior of the automobile. For participants who collaborated through voice conference call the questions were "Did you miss visual information of your collaborator?" and "If a video stream was included to the call, would your results change?" whereas for participants who collaborated through video conference call the questions were "Did you check the screen to see your collaborator?" and "If the video was removed from the call, would your results change?" Those questions were selected in order to determine to which extent the participants perceived the inclusion of video stream as relevant for remote collaboration (Figure 27).

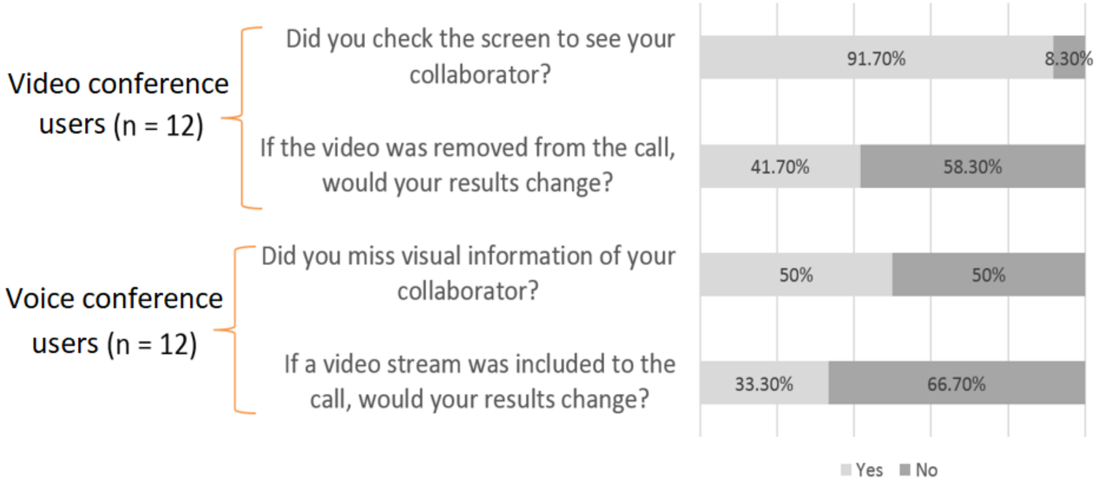


FIGURE 27: QUESTIONS ASKED AND ANSWERS COLLECTED AFTER EACH STUDY

The answers to the complementary interview suggested that the incorporation of a video stream was considered by participants somewhat desirable but not necessary for the achievement of 'successful' collaboration on the road. The main researcher also noted that drivers who used video conference to collaborate only checked the screen when they were stopped at a traffic light, due to high traffic conditions or because they got lost and stopped the automobile to focus on finding a solution with their partner through the use of body language and gestures with the hands.

On the other hand, drivers perceived their interaction partners as more involved in the conversation than research collaborators did. Although the tasks accomplished during the tests were designed to encourage teamwork, drivers perceived their partners as more involved in the interaction than themselves. This effect can be due to their mental resources to be oriented to driving rather than to speaking to their collaborator, ultimately leading drivers to feel 'distracted' by the conversation.

Finally, and by no means the least important, there was a difference of opinions regarding social presence depending on the role assigned to the participants. Research collaborators reported the video conference tool to provide a better medium to connect people while drivers preferred conferences to be connected with their partners. Being located in a separated room without visual feedback from the automobile contributed to a feeling of isolation in the collaborators while on the other hand, drivers had enough stimuli from the simulation to not miss such information from their collaborator. This issue aligned with a study carried by Schroeder and Epley (2016) where they observed that adding voice to a communication channel with a chatbot affected significantly to the anthropomorphism perceived by users whereas adding visual content did not. They concluded indeed, suggesting that the addition of video to the communication could potentially lead to distract the observer rather than to add value to the communication. Therefore, it appears reasonable that for real-time remote collaboration between drivers and designers, the speech included most of the relevant information exchanged under the experimental conditions.

Summarising these issues, the voice conference call was reported as effective as the video conference call to support remote collaboration in terms of presence perception, and the majority of the participants (15 of the 24 who took part in total) declared that they did not find the video stream as a requisite to complete the tasks they were asked to complete. Therefore, voice conference call technologies were prioritised to support real-time remote collaboration between automobile drivers and designers.

5.6 Limitations

Similarly to the case described in Chapter 4, this study presented some limitations. Firstly, the experiment described in the previous sections was conducted through the use of a driving simulator. Again, despite driving simulators have been widely used for research purposes, these tools can never fully replace the experience of driving a real automobile in an actual environment (Lucas, et al., 2020). Therefore, this sometimes leads researchers to collect results which differ to those potentially taken under real driving conditions.

On the other hand, although the structure of the results showed parallelism with the paper where the scale was validated (co-presence reported higher values than social presence), the results did not provide any significant difference. Thus, the communication channel to conduct real-time collaboration was selected based on the subjective analysis conducted on the results with reduced statistical support. For instance, if the sample size was increased ($n = 24$, which made $n = 6$ for each one of the sub-groups such as drivers using voice conference or drivers using video conference), the power of the statistics would increase accordingly. However, if that was the case, the results might remain equal. Additionally and in relation to the validity of the questionnaires to measure the presence, it has been suggested to use both objective and subjective measurement approaches to validate the results instead of using only one of them, whereas only one questionnaire was used in this study (Baren and IJsselstejin, 2004). This might have led to a partial insight in regards to the nature of the remote collaboration under investigation.

5.7 Conclusion

The motivation of the study included in this chapter was to create a better understanding in regards to the effect of the communication channel on the drivers' perception of presence and to confirm whether one of two specific CMC tools composed a more acceptable medium to support a real-time collaborative dialogue. To that end, a set of activities was performed by participants while they were either driving or speaking from a control room. Subsequently, the participants were provided and asked to complete a post-task questionnaire in order to report the experienced presence feeling.

Results rejected the hypotheses that voice conference calls create lower values of presence than video conference calls even though they did not include visual information about the interaction partner. Indeed, voice conference calls were reported providing a more realistic feeling of presence, suggesting video conferences to be distractive for drivers and less natural to be used while driving under the experimental conditions. Moreover, a difference between the perception of presence on collaborators and drivers was found, suggesting that the different activities performed during the communications affected the users' perception of their interaction partners.

Thus, the study of presence perception applied to the driving simulator suggested that under the study conditions described in the previous sections, only-voice-based CMC technologies can provide an effective solution to support real-time interaction between designers and automobile drivers. In sum, although the results of this experiment were not statistically significant, they paved the way to select the channel to support the conversations: the voice conference call.

Once the communication channel was selected, the next chapters shift towards the dialogue between collaborators (see section 1.7). Therefore, the next step for the consecution this research involved the evaluation of the possible benefits of interviewing drivers while they were operating an automobile in terms of the information collected.

6. Study 3: Exploring the Possible Benefits of Conducting Real-Time Remote Contextual Inquiry with Drivers

6.1 Introduction

As discussed in Chapter 1, this research aimed to study the applicability of remote contextual inquiry between automotive designers and automobile drivers. In turn, it was decided to explore the *communication hardware* and *channel* requirements for the collection of real-time information from drivers, as well as the possible benefits of this approach for the collection of valuable information. To that end, a literature review was conducted and included in Chapter 2. Subsequently, the methodology followed across this research was described in Chapter 3. Then, Chapter 4 discussed the effect that the characteristics of the *communication hardware* have on the driver and Chapter 5 developed a further analysis in regards to the perception of virtual presence by automobile drivers with a study to define the *communication channel* requirements. The next step towards the completion of the research described in this document involved the study of the possible benefits of the *interview* between the designer and the driver, by means of its potential for the collection of valuable information.

Oxford English Dictionary defines valuable as "extremely useful or important" where refers to 'useful' as "able to be used for a practical purpose or in several ways". Therefore, a more complete definition for 'valuable information' states "information that can be used for a practical purpose or in several ways". As discussed in Chapter 2, in this research it was assumed that more quantity and more variety of information correlated with more value to automotive designers (Pedersen, 2019). Therefore, by combining these definitions with the aims of the research (see section 1.6) in this document *valuable information* refers to *a quantity and variety of information that can be potentially used for the development of new automotive product and service concepts*.

Among the alternative findings of the literature review, contextual inquiry was selected to retrieve in-context customer experience information and therefore, to compose the *dialogue* between automotive designers and drivers during real-time remote collaborative sessions (see section 2.6.1 for further detail). Contextual inquiry is a form of an interview, which in turn is a research method typically used to collect personal accounts of experience, opinions, attitudes and perceptions (Berndt, Furniss, and Blandford, 2015; Coble et al., 1995). These forms of information are typically shaped as qualitative data and it is obtained from direct contact with participants (Martin and Hanington, 2012). In order to assess how valuable is the information typically collected through the interviews, four qualitative analysis methods were reviewed (Johnson, Scheitle, and Ecklund, 2019; Thomas, 2006). These methods were discourse analysis, inductive analysis, grounded theory and phenomenological analysis. As shown in section 2.6.1, among these approaches, discourse analysis and inductive analysis were prioritised to assess whether the information collected from the interviews was valuable in this research. This decision was made upon their simplicity and capacity to provide estimates for quantity and variety of information.

On the other hand, recent research suggested that the implementation of real-time collaborative sessions in automobiles offer to automotive designers the opportunity to engage drivers into a *creative dialogue* (Gkatzidou, Giacomin, and Skrypchuk, 2016). Scholars typically use the concept of '*creativity*' interchangeably with '*invention*', '*imagination*' or '*innovation*' (Kaufman, Plucker, and Russell, 2011; Plucker and Makel, 2010; Treffinger et al., 2002). Although recent literature combined the study of the discourse and creativity (Meyer, et al., 2019), there is no substantial proof of contextual inquiry in automobiles contributing to collect valuable information, or more specifically, innovative concepts. This paved the way to investigate whether contextual inquiry can be used to collect creative answers. Thus, the data collected through the interview was also analysed through the use of creativity-based instruments. In order to explore whether the in-context interview was compatible with creative achievement, the concept of 'creativity' was reviewed in section 2.6.3. Such a review showed the 'product' approach described by Said-Metwaly et al. (2017) as the most suitable candidate to evaluate creativity in the answers of an interview. This approach referred to *creative achievement* as "the outcome of a development process in which a piece of work is fully created by an individual and is labelled as 'creative' by an expert panel based on predefined criteria".

In summary, to explore the possible benefits of implementing contextual inquiry inside automobiles, an interview was designed based on the guidelines found in the literature and tested in two research scenarios (Torrance, 2008; Strachan, 2007; Foddy, 1993). Such interview aimed to prompt a creative dialogue and it was tested in both a bare isolated room and the interior of an automobile. Thus, this chapter investigates possible differences between interviewing drivers while they were out of the automobile and interviewing them while they were operating an automobile. In turn, the following sections describe a study designed under the assumption that in-context interviewing offers a set of stimuli to the respondents that affect their discourse, and which aimed to confirm whether the interior of the automobile composes a suitable environment for the implementation of a real-time collaborative dialogue, by answering the next research question: *'What are the benefits of contextual inquiry when it is conducted remotely while the driver is operating the automobile?'*

6.2 Aim

As seen in the previous section, a study was conducted to confirm whether in-context interviewing can provide valuable information to automotive designers. To that end, it was followed a deductive approach to interview drivers in two experimental conditions. The first of the conditions was while participants were sitting in an interview room (as a control sample) and the second of the conditions was while participants were operating an automobile. The interview was designed based on the principles of effective interviewing found in the literature (Strachan, 2007; Foddy, 1993) and the answers provided by the respondents were analysed in terms of discourse, the general inductive approach and the 'product' approach for creative achievement proposed by Said-Metwaly (2017). In order to respond the research question, three research hypotheses were proposed:

i. *The in-context interview provides more valuable information in terms of discourse quantity and variety*.
ii. *The in-context interview provides more valuable information in terms of themes covered*.
iii. *The in-context interview provides more valuable information in terms of creative achievement*.

6.3 Methodology

Once discussed the alternative methods to assess whether in-context interviewing can be considered an effective approach to collect valuable information from automobile drivers and proposed alternative research hypotheses, a 1x2 between-subjects experiment was conducted. In the experiment, all the participants were individually interviewed only once, in order to avoid learning effects. The independent variable studied with the experiment was the *environment* where the participant was located *while being interviewed* and it had with two study conditions – (i) Isolated room or (ii) Driving simulator. Thus, isolated room will refer onwards to a telephone interview conducted while the respondent was located in a bare isolated room, whereas driving simulator will refer to the in-context interview conditions.

6.3.1 Measurement instruments

For the collection of qualitative data through the use of interviews, the studies are typically recorded and subsequently transcribed (Lazar, Feng, and Hochheiser, 2017). The factor most frequently analysed in the data collected from interviews is the verbal responses to the questions. It is worth noting that non-verbal responses such as pauses, intonation or body language are also of frequently investigated (Baker, 2006). However, in this case it was decided to limit the scope to verbal responses for their potentially higher relevance in remote co-design sessions over the non-verbal responses. Thus, all the interviews were driven, recorded and transcribed manually by the main researcher in full including expressions and pauses. The voice recorder used to record the conversations was the "*Voice Memos*" app installed by default in an iPhone SE. Once all the interviews were transcribed, in order to address each of the issues raised in section 6.2, the transcriptions were analysed through the next three techniques:

Discourse analysis. The main goal of discourse analysis is to understand how people use language to create and enact identities through the study of *messages* in terms of linguistics and semiotics (Starks and Trinidad, 2007). The study of discourse can be addressed following different approaches which can be selected depending on the study objectives. The most frequent approaches involve the analysis of the most frequent words, the vocabulary, relationships between words, etc. (Baker, 2006). Due to discourse analysis composing one third of the data analysis of the study instead of the complete data analysis process, it was decided to select the simplest of these alternatives, being the analysis of frequencies. Therefore, it was analysed the *total number of words* spoken by participants, *word variety* (number of unique words which occur in the transcript), *word frequencies* (number of times that specific words occur in each study condition) and *word relative frequencies* (number of times that a specific word occur in the message referred to the total number of words included in the full body of the message). These analyses were performed using the version 7.0 of an automatic tool called "*WordSmith Tools" and the version 12 of "NVivo Pro"*. The first of these tools was used for the statistical analyses due to its reduced difficulty to use and the second of these tools was selected to generate the infographics. To complete the analysis, it was also observed the length of the interview in *minutes*, which refer to the time span since the interviewer started pronouncing the first question to the moment in which the respondents stopped providing the last answer.

Thematic analysis. The method selected to perform thematic analysis is the General Inductive Approach for its simplicity and effectiveness to explore repeating topics in the data (Thomas, 2006). This approach consists on a set of procedures designed to create summary themes or categories from the raw data. According to the literature, these procedures are the identification of specific text segments related to objectives, the development of labels for those segments in order to create text categories, the reduction of redundancy among categories and finally, the creation of a model incorporating the most important categories (Thomas, 2006). This method usually involves 2-3 iterations and the collaboration between coders in order to maximise trustworthiness and minimise coder bias (Lombard, et al., 2006).

Creativity assessment. In order to measure the creativity of the answers, it was followed the *product* approach mentioned in section 2.6.3. To that end, the instrument selected was the Consensual Assessment Technique (Amabile, 1982) based on the principles of the Delphi Method (Skulmoski, Hartman, and Krahn, 2007). These techniques are based on the judgement of a panel of experts (see Appendix F.3) and for the study described in this chapter, the criteria to select the members of the panel (n = 6) is presented next:

- Psychologists (n = 2) with a PhD and a minimum of 3 years of working experience working in their sector. A significant amount of literature regarding the measurement of Creativity is provided by psychologists (Said-Metwaly, et al., 2017), which suggests that such professionals are familiar with the assessment of qualitative data.
- Designers (n = 2) with a PhD and a minimum of 3 years of working experience in their sector. The research described in this document aimed to develop an interview to be used by Designers, therefore they were included in the development and evaluation of such interview.
- Researchers (n = 2) currently working in the Automotive Industry with a minimum of 3 years of experience in their sector. These professionals were included in the assessment of creative ideas due to their familiarity with the concepts used in the interview.

6.3.2 Stimulus materials

The interview. As described in Chapter 1, one of the aims of this research involved exploring the benefits of contextual inquiry when it is conducted remotely while the driver is operating the automobile. Contextual inquiry is a research method which relies on the collection of data in the context where customers use a given product, to explore which characteristics of the product can be reworked for its 'optimal' use. The collection of such data is typically conducted via semi-structured interviews (Rosenzweig, 2015). Additionally, researchers proposing the use of contextual inquiry inside automobiles advocated for the use of such interviews to prompt a 'creative dialogue' between designers and drivers (Gkatzidou, Giacomin, and Skrypchuk, 2016). Following those suggestions, it was designed a semi-structured interview which aimed to collect both customer feedback and improvement ideas for future automobiles. Accordingly, the design of the interview was based on the literature review findings which were discussed in section 2.6.3. On the one hand, the structure of the interview was based on Strachan's 5 Processes Framework (Strachan, 2007) and the wording of the questions was designed and reviewed according to the suggestions made by Foddy (1993) with the 'TAP' paradigm. On the other hand, the core questions of the interview included activities typically used in the verbal version of the Torrance Test of Creative Thinking (Torrance, 2008) which have been frequently associated with the 'creative process' (see section 2.7.3). In turn, these activities were adapted to the automotive context as follows:

- Activity 1: To reflect on the typical usage provided to the in-vehicle navigation system (i.e. typical destinations, the frequency of usage, etc.).
- Activity 2: To estimate the causes of a failure using the in-vehicle navigation system (i.e. if you are using the navigation system and you still get lost, guess possible reasons).
- Activity 3: To predict the consequences of a failure using the in-vehicle navigation system (i.e. if you are using the navigation system and you still get lost, guess possible consequences).
- Activity 4: To propose a product improvement (i.e. how would you improve the in-vehicle navigation system? would you add any functionality to the system? etc.).
- Activity 5: To search unusual uses for the product (i.e. could you find non-typical applications for the in-vehicle navigation system?).
- Activity 6: To deduce the outcomes and consequences of an improbable situation (i.e. what could happen if the in-vehicle navigation system was able to decide your destination for you?).

In the automotive environment, the length of the dialogue between designers and drivers was limited for timing restrictions, in order to reduce the time that the drivers are dividing their attention into the driving task and the dialogue. This led to the use of a unique question for each of the activities described in the previous lines in addition to an optional follow-up question in case the answer provided by the respondent was not initially justified. The main topic selected for the creative conversation is the In-Vehicle Navigation System (IVNS) for being considered one of the main sources of distractions in the automotive environment and hence, an example of technology to potentially improve in the future (Lee, et al., 2014). To provide an insight into the contents of the dialogue, the stages of the interview, the questions used, and explanation of their objectives were summarised and listed next to the source of literature where such piece of the interview was suggested to take place (Table 16). For the full script of the interview see Appendix G.3.

<table>
<tr><th>Stage</th><th>Question</th><th>Objective</th><th>Reference</th></tr>
<tr><td>Opening</td><td>Good afternoon XXXX, how are you?

As a quick reminder, this interview aims to […] Does it sound ok to you?</td><td>Create compliance</td><td>Foot in the Door Technique by Freedman and Fraser (1966)

Words that sell by Brudner (2018)</td></tr>
<tr><td rowspan="5">Enabling Action</td><td>Every story has a beginning and I would like to know how yours started… So how many years have you been driving so far?</td><td rowspan="2">Create a storyline structure to introduce a logical order with the questions</td><td rowspan="5">Introducing the 5 Process Frameworks Strachan (2007)

The TAP Paradigm by Foddy (1993)</td></tr>
<tr><td>How old were you when you got the driving license?</td></tr>
<tr><td>What was your motivation for getting the driving license?</td><td rowspan="3">Retrieving ethnographic data and narrowing down to the main topic</td></tr>
<tr><td>Do you usually drive? How many days a week-month-year?</td></tr>
<tr><td>How often do you use a navigation system?</td></tr>
<tr><td rowspan="2">Thinking critically</td><td>How would you describe the overall process of setting up and using the navigation tool?</td><td>Ask and guess about a general topic</td><td rowspan="2">TTCT verbal by Torrance (2008)</td></tr>
<tr><td>Have you ever gotten lost even though you were using a navigation tool? What happened? Did it have any specific consequence?</td><td>Guess causes and consequences of a product failure</td></tr>
<tr><td rowspan="3">Addressing the main event</td><td>Do you think there is any way these tools could be improved?</td><td>Product improvement</td><td rowspan="3">TTCT verbal by Torrance (2008)</td></tr>
<tr><td>Now let's think out of the box, apart from guiding us to the place we want to go, could you find an alternative use for a navigation tool?</td><td>Unusual uses for the device</td></tr>
<tr><td>Imagine one day you did not have any plan for your evening, what would you think if the navigation tool could give you some suggestions?</td><td>Consequences of an improbable event</td></tr>
<tr><td rowspan="2">Closing</td><td>Let's get back to you, if you were to write a newspaper headline to summarise your experience with these tools what would it be?</td><td rowspan="2">Summarise their experience with their own words in a predefined context</td><td rowspan="2">The Creative limitation by Runco (2014)</td></tr>
<tr><td>Which emotion would you use to describe your overall experience with navigation systems?</td></tr>
</table>

TABLE 16: TAXONOMY OF THE INTERVIEW

The driving simulator. One driving simulator was used in order to recreate the automotive environment. The decision was made upon the capacities that driving simulators have to provide a controllable environment, to ease the data collection and low-cost testing according to the literature (Bella, 2014). The driving simulator used in this study was composed of three main elements: a BMW Mini body shell, a computer installed under the bonnet for the signal processing of the devices integrated within the automobile (i.e. steering wheel, gearbox, pedals, etc.) and lastly another computer installed in a separated room (called control room onwards), used to support the simulation and monitoring software (Figure 28).

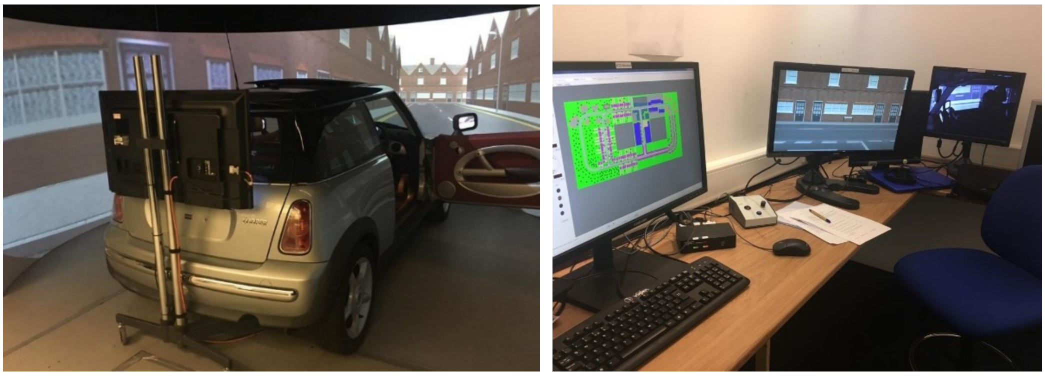


FIGURE 28: BMW MINI BODY SHELL, SCREEN, AND MONITORS AT THE CONTROL ROOM

The software used to support the simulation was included in the Advance Driving Package simulation software called “XPI DS2 Full Car Simulator”. The computers used to process the signals from de on-board equipment as well as to monitor the participants’ behaviour from the control room had Microsoft Windows 7 Professional 64 bit as the operative system, an Intel Core i7 3.40 GHz as a processor and 5 GB of RAM. The scenario projected for the simulation included light raining, the light conditions of 2 pm and low-medium traffic conditions (40% of the capacity the software can simulate). In terms of the map simulated, recent literature suggested that from human factors and ergonomics perspectives, the recommended ratio for the road types is 40% urban roads, 40% country roads and 20% highways (Weber, et al., 2019). In this research, urban roads refer to those major and minor roads within a settlement of population of 10,000 or more, rural roads refer to major and minor roads without urban settlements, and highways refer to motorways and all ‘A’ roads (DFT, 2017). However, the studio described in this chapter was planned to be replicated under real driving conditions as described in Table 10, included in section 3.5. Those real driving conditions were planned to occur in the area surrounding Brunel University of London for time-efficiency reasons. Therefore, the ratio of the road types considered for the map simulation was adjusted to replicate the area where Brunel University is located, which is named Uxbridge and is located in the Borough of Hillingdon (London, United Kingdom).

According to the population statistics report made by the Greater London Authority (GLA, 2019), the population of Uxbridge in 2016 was 30733. This triples the minimum of 10000 population required by the UK Department of Transport to consider an area as urban (DFT, 2017), suggesting that urban roads ratio may be in this case significantly higher than the 40% proposed in previous literature (Weber et al., 2019). Therefore, as an attempt to replicate the road ratios which were expected to find in Uxbridge for study 4, it was decided to use a ratio of 75% urban scenarios, 15% country roads and 10% highways.

To display those virtual scenarios, it was used a projection screen which is 2 meters height and curved in a radius of 2.65 meters to provide a 270° view from the driver's seat through the use of five WUX4000 projectors hanging on top of the body shell's roof. The LCD panel resolution provided by such projectors is 1920 x 1200 (WUXGA), which involved a total of 2304000 pixels with an image ratio of 16:10. Behind the body shell of the automobile located where the rear mirror points, there is installed an LG TV with an LCD screen of 42 inches and a resolution of 1920 x 1080 (HDTV).

On the other hand, the participants who completed the interview by phone from an isolated room were kindly requested previously to the session to allocate themselves and stay in a comfortable room where they would not expect to be interrupted or distracted during the interview.

6.3.3 Participants and recruitment

The minimum of participants required to be interviewed in this experiment was fixed to 18 for data saturation reasons according to the suggestions in the literature (Francis, et al., 2010). However, a total of 34 participants took part in the study. Unfortunately, 6 of them (1 male and 5 female) experienced simulator sickness during the interview in the driving simulator, which forced their results to be excluded from the study. This issue reduced the sample size to 28 participants (n = 28) who successfully took part in the study, including 14 respondents interviewed through a telephone call while sitting in an isolated room and 14 respondents interviewed while steering the driving simulator as described in the previous section (each participant was interviewed only once to reduce learning effects). These participants were 50% male and 50% female equally distributed between both groups (7 male interviewed through the phone and 7 male interviewed at the driving simulator; same with the female participants). The sample had an average age of 26 (SD = 3) with a range of 21-36 years old and an average of 6 years of experience driving (SD = 4) with a range of 1-18 years holding the driving license.

Regarding the evaluation of Creativity in the ideas, the selected panel of experts (Amabile, 1982) was composed of 6 members with a minimum of 3 years of experience in the fields of in Psychology, Design and R&D within the Automotive Industry. The selection criteria for the members of the panel was discussed in section 2.6.3 (Surowiecki, 2004).

The selection of participants, as well as all stages of the tests, were performed under Brunel University's full ethics approval and in compliance with the pertinent ethics policy (see Appendix E). As part of such process, all participants were informed about the goals of the experiment (see Appendix A) and asked to complete a form agreeing to take part in the study (see Appendix D). Additionally, the candidates for the interview in the simulator were asked to answer a screening questionnaire before any test in order to reduce the incidence of simulator sickness (see Appendix B) and after the experiment to ensure they were not dangerously affected by the simulator (see Appendix C).

6.3.4 Study protocol

As described in section 6.3, all the participants taking part in this study were interviewed in either one of two conditions. Depending on the study condition of each test, a different study protocol was followed:

Interviews from an isolated room. Participants were contacted by email to arrange a meeting when according to their preference they could be interviewed from a quiet place where they felt comfortable and uninterrupted. The respondents were contacted by the researcher 15 minutes previous to the interview via text message in order to ensure they remembered they would be called in few minutes and to encourage them to move to the quiet place they previously selected to stay during the interview. Once the telephone call started, they were asked introductory questions and informed about the goals of the interview previous to start addressing the main topic of the conversation (see Appendix G.3).

Interviews from the driving simulator. Previous to start working with the simulator, the respondents were explained the goals of the experiment as well as a summary of what they were expected to do. Subsequently, as a short introduction in order to allow the participants to become familiar with the driving simulator, they were asked to freely drive through a simple scenario without traffic or any special conditions (i.e. extreme weather or obstacles on the road). All the participants were encouraged to notify when they felt comfortable with the driving simulator and ready to start with the actual test. Such a process typically took between 2 and 5 minutes. After that, the map of the driving simulator was replaced by another scenario which included other automobiles and obstacles on the road in order to add realism to the test. Then, the participants were asked to drive freely through the map and after two minutes they were contacted by the researcher to start the interview.

6.4 Results

In order to create a basic understanding of the ethnographic nature of the data collected, a preliminary analysis was conducted prior to address the research hypotheses.

Such preliminary analysis showed that 29% of the respondents (n = 8) tended to employ a navigation tool at least once a week, 17% of the participants (n = 5) once every month and 54% of the interviewees (n = 15) argued that they only employ these tools in rare occasions which take place every few months. In regards to the navigation tool preferences, 54% of the participants (n = 15) focused their answers on the In-Vehicle Navigation System (IVNS) while 46% of the respondents (n = 13) chose to answer the questions based on their experience using alternative navigation tools such as ‘Google Maps’, ‘Apple Maps’ or ‘City Mapper’. Furthermore, 39% of the participants used to drive at least once a week (n = 13), 15% once every month (n = 4) and 46% declared that they used to drive at least once every few months (n = 11) mostly because they did not own an automobile in the country where the interview took place (Figure 29).

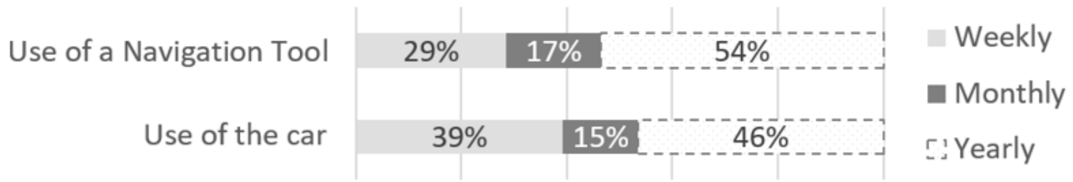


FIGURE 29: REPORTED FREQUENCY OF USAGE FOR AUTOMOBILES AND NAVIGATION TOOLS IN STUDY 3

For the resolution of the proposed Hypotheses, three procedures were applied in correlation to the metrics described in section 6.3.1:

Discourse analysis: The statistical test selected to investigate the effects of the context in which the interview was conducted on the discourse was the 2-tailed independent samples t-test. According to the literature (Lazar, Feng, and Hochheiser, 2017), this is the optimal approach to analyse data in between-groups studies which involve one independent variable (i.e. interview context) with two study conditions (i.e. isolated room or driving simulator). Thus, variables such as number of spoken words, variety of vocabulary used, or length of the interview were analysed with separate t-tests. Moreover, since the sample size of this study was relatively small (i.e. 28 participants who were divided into two groups of 14), it was decided to calculate the statistical power of the previous analyses with $\alpha = 0.05$ in order to provide more solid conclusions from the study.

Thematic analysis: In order to reduce bias introduced by the structure of the interview, the General Inductive Approach was only applied to the answers of the six activities that according to the literature were associated with creative process (see section 6.3.2). These questions aimed to collect improvement ideas and therefore, that was the focus of the coders when conducting the thematic analysis: *identify and categorise improvement ideas* proposed during the interviews. Once the pieces of transcript corresponding to those questions and answers were identified and separated from the original transcripts of the interviews, it was performed a thematic coding according to the guidelines proposed by previous literature (Thomas, 2006). The information managed throughout the thematic coding process included pieces of the original transcriptions all the time and in order to ensure a minimum of coding consistency, an independent parallel coding was performed with a total of 4 coders over 3 iterations for the coding consistency check. The percentage of agreement established as the minimum was 90%. According to the literature, this percentage of agreement usually ranges from 50 to 90% to be considered 'acceptable' (Lombard, et al., 2006).

To proceed with the analysis, the main researcher read the answers of the participants and developed a set of ideas and categories that constituted the preliminary findings. A second coder was provided the list of ideas created by the main researcher used as well as the evaluation objectives. Without seeing the initial categories, the second coder was asked to confirm whether the ideas had been correctly selected from the answers of the participants, and to create a second set of categories from the raw text. Such second set of categories was compared with the first set to establish the extent of overlap. Then, the two sets of categories were combined into a third set and a third coder was provided with the ideas and the evaluation objectives. The process was repeated. In this case, the overlap between the categories was high, so these ideas and categories were fixed. Then, a fourth collaborator was contacted and asked to classify the ideas within these fixed categories. This fourth collaborator classified exactly 90% of the ideas under the same categories the previous coders did, suggesting that a reasonable level of agreement between coders was reached.

In order to understand if the participants covered more topics in one of the conditions, it was analysed if any of the categories developed by the coders included exclusively ideas proposed by participants in one of the conditions (driving simulator vs. isolated room).

Creativity assessment: The experts were asked to provide their own definition for Creativity as well as a suggestion to measure such construct in ideas (see Appendix F.3). Additionally, they were provided of a list with the answers of the participants to the question *"If you were to write a newspaper headline to summarise your experience with navigation systems what would it be?"* randomly sorted and asked to sort these ideas by order of creativity according to their predefined criteria. That question was selected to measure the creative outcomes of the interview for its potential to generate personal and normalised ideas, easing the comparison between the two conditions of the study. Other questions aiming to collect ideas to improve the user experience inside the automobile were rejected for this purpose due to the implicit difficulties in normalising and comparing the answers received (i.e. similar but not exactly equal ideas collected in both conditions, similar ideas discussed with different levels of detail, bias introduced by the researcher, etc.).

Once the experts sorted the newspaper headlines according to their criteria these ideas were weighted with a number of points according to their position in the ranking and the analytic hierarchy process was applied (Saaty, 2008). In this case, having a sample size of n = 28 involved assigning 28 points to the most creative idea and 1 to the least creative idea in each ranking. Then, after the evaluation of all the members of the expert panel, the ideas accumulated an absolute count of points based on their different positions in the rankings. In order to ease comparison between these ideas, a performance indicator was generated for each idea. To that end, the maximum possible score, which was 28 points multiplied by the 6 experts of the panel, was fixed to 168 points. Such amount of points represented the '100% creative idea' and all the scores accumulated by the ideas were subsequently referred as a percentage to explain their performance in terms of creativity (for instance, an answer which accumulated a total of 52 points upper the maximum of 168 was rated with a score of 30.9 for being 52 points the 30.9% of 168; thus, that answer was considered 30.9% creative). Then, an independent samples t-test was conducted to compare the scores of the answers gathered in both conditions (isolated room and driving simulator).

To provide an insight into the outcomes of the statistical tests which were conducted during this study, the acceptance and rejection of the null hypotheses which were proposed were summarised (Table 17). Moreover, the following sections describe the detailed resolution of each one of these research hypotheses.

Independent Variable	Dependent Variable	Null Hypothesis
Context of the Interview	Word count and variety	**Rejected**
	Themes covered	Accepted
	Creativity	**Rejected**

TABLE 17: SUMMARY OF THE HYPOTHESES VALIDATION FOR STUDY 3

6.4.1 The effect of driving on the discourse

Hypothesis 1: The in-context interview provides more valuable information than the interview conducted from an isolated room in terms of discourse quantity and variety. This hypothesis was supported. The in-context interview provided more quantity and more variety of information than the interview conducted form an isolated room in terms of discourse.

The effect of in-context interviewing under real driving conditions on the discourse regarding the number of total spoken words was significant: $t (26) = 2.479$, $p = 0.020$; $P = 0.665$. Interviews that took place while the participants were using the driving simulator involved a larger amount of total spoken words ($M = 1375$; $SD = 332$) than interviews that took place while the respondents were located in an isolated room ($M = 1125$; $SD = 178$). Moreover, participants who answered the questions from the driving simulator provided longer answers in terms of the number of words ($M = 880$; $SD = 285$) than those who were interviewed from an isolated rooms ($M = 586$; $SD = 205$). Such difference was also statistically significant: $t (26) = 3.135$, $p = 0.004$; $P = 0.855$. On the other hand, in regards to the number of words spoken by the interviewer, the difference between the two conditions was not significant: $t (26) = 1.061$, $p = 0.299$. In this case, the researcher pronounced more words during the interviews from an isolated room ($M = 539$, $SD = 95$) than during the interviews from the driving simulator ($M = 495$, $SD = 121$).

Regarding the variety of the vocabulary used in both conditions, the in-context interview (driving simulator) provided more valuable information in terms of varied vocabulary (M = 249 different words used per interview; SD = 52 words) than the interview from the isolated room (M = 200 different words used per interview; SD = 43 words). This difference was statistically significant according to the outcomes of the independent samples t-test ($t (26) = 2.760$, $p = 0.010$; $P = 0.757$).

In terms of word frequency (Table 18 and Figure 30), it was analysed the most used nouns for both conditions, as well as the number of times that they occur (N) in total, and the percentage of times that they were used compared to the total number of words used in each condition (%). For instance, ‘car’ was used 36 times in the driving simulator, representing the 0.43 % of words spoken in such condition. The words in *cursive* are those not shared by the two experimental conditions.

Isolated Room			Driving Simulator		
Word	**N**	**%**	**Word**	**N**	**%**
Car	58	0.47	Car	36	0.43
Time	43	0.35	Navigation	36	0.43
Example	42	0.34	GPS	35	0.42
Navigation	41	0.33	Time	33	0.4
Road	39	0.32	Maps	27	0.32
Way	37	0.3	Places	26	0.31
Google	35	0.28	Example	24	0.29
Maps	35	0.28	Google	24	0.29
Place	28	0.23	Place	22	0.26
GPS	23	0.19	Way	20	0.24
System	23	0.19	Years	20	0.24
Years	22	0.18	System	18	0.22
Phone	*20*	*0.16*	*Map*	*17*	*0.2*
Places	18	0.14	Road	16	0.19
Thing	*18*	*0.14*	*Day*	*15*	*0.18*

TABLE 18: SUMMARY OF THE 15 MOST FREQUENTLY SPOKEN NOUNS IN BOTH CONDITIONS OF STUDY 3

On the other hand, the most frequent words used in both conditions according to the software tool called “NVivo 12 Pro” were presented in info-graphics for the analysis of discourses (Figure 30). To create a more general insight into the content of the interviews, these figures were generated based on the automatic option of the software to create groups of words based on generalised concepts. To that end, the tool “NVivo 12 Pro” allows grouping words automatically based on exact matches or individually (i.e. “talk”), with stemmed words (i.e. “talking”), with synonyms (i.e. “speak”), with specialisations (i.e. “whisper”), or with generalisations (i.e. “communicate”). The option used to generate the infographics shown was the last of these alternatives. In turn, words with greater sizes correlate with concepts more frequently referred to in each study condition. Again, the most frequently mentioned concepts were shared in both conditions and this can be associated with the automotive nature of the interview (i.e. change, activities, driving, etc.). Alternatively, words referring to specific concepts were used less frequently, which can be associated with the specific nature of the experiences which were narrated by each participant (i.e. day, phone, GPS, message, program, etc.).

WORD CLOUD FOR ISOLATED ROOM CONDITIONS

WORD CLOUD FOR DRIVING SIMULATOR CONDITIONS

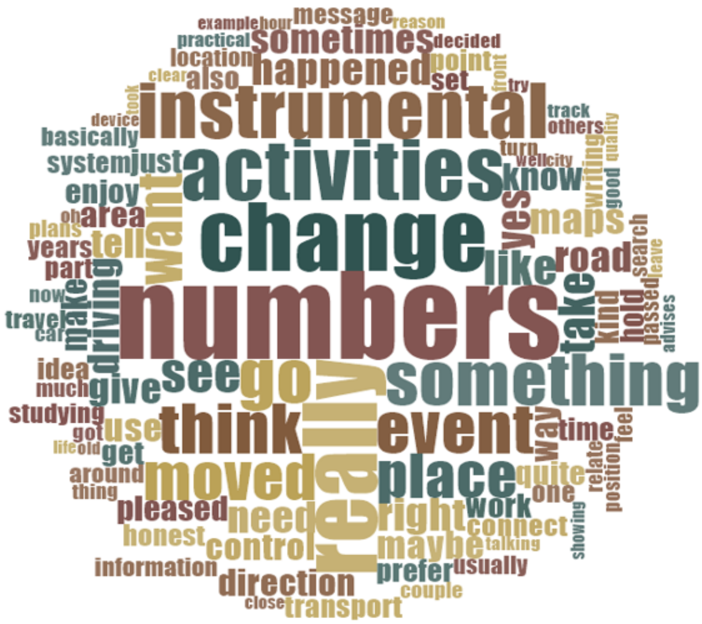


FIGURE 30: WORD CLOUDS FOR THE MOST FREQUENT LEXICAL WORDS OF BOTH CONDITIONS IN STUDY 3

In addition, the interviews that took place while the respondents were using the driving simulator (M = 552, SD = 164) did not last for longer than interviews that took place while the participants were located in an isolated room (M = 575, SD = 129). The difference between these two conditions is not significant: t (26) = 0.413, p = 0.683. Interview length was expressed in seconds and measured from the instant in which the interviewer started asking the first question to the moment in which the respondent stopped answering the last question.

Lastly, an additional analysis was conducted in order to estimate the verbal fluency of the participants (Baker, 2006). Respondents who were interviewed while using the driving simulator pronounced more words per minute (M = 96, SD = 14) than participants who were interviewed from an isolated room (M = 62, SD = 20). Such difference was statistically significant: t (26) = 5.133, p = 0.000; P = 0.999. It is worth noting that this difference should not be confused with the concept of verbal fluency, since the timing involved in its calculation also include periods in which the interviewer was also speaking, and verbal fluency usually refers to the number of words semantically connected that an individual can pronounce per unit of time (Shao, et al., 2014). Therefore, these results represent an estimation of the amount of information that respondents can potentially provide per unit of time. On the other hand, the ratio of words that was spoken by participant per word that was spoken by the interviewer was higher in the driving simulator (M = 1.85, SD = 0.65) than in the isolated room (M = 1.15, SD = 0.53). This difference was significant (t (26) = 3.141, p = 0.004; P = 0.856). The general values analysed for the evaluation of the effect of the environment on the discourse were summarised (Table 19).

		Participant words	Participant words variety	Seconds	Minutes	Participant words per minute
Isolated room	MEAN	586	200	575	9'35"	62
	SD	205	43	129	2'9"	20
Driving simulator	MEAN	880	249	552	9'12"	96
	SD	285	52	164	2'44"	14

TABLE 19: MEAN AND STANDARD DEVIATION FOR WORDS SPOKEN BY PARTICIPANTS AND INTERVIEW LENGTHS IN STUDY 3

6.4.2 The effect of driving on the themes covered

Hypothesis 2: The in-context interview provides more valuable information than the interview from isolated room in terms of themes covered. This hypothesis was not supported.

A total of 40 improvement ideas were collected by the coders from the raw data of all the transcribed interviews. Subsequently, the coders classified the ideas according the procedure described in section 6.4 concluding with three main categories. None of these categories was composed exclusively by ideas collected in one of the experimental conditions, rejecting then the hypothesis 2. Generally, interviewees proposed improvements and new capabilities for the IVNS regarding the instructions, the connectivity of the device to the network, and how to customise the use of such tool to the specific needs of any individual. These themes were selected by the coders with an agreement of 0.9 (36 ideas of 40) and were labelled as follows:

Instructions: The suggestions made to improve how the instructions are typically provided ranged from visual issues such as the use of real pictures of the street or Head-Up Display (Previc and Ercoline, 2004) to verbal issues such as the anticipation or the words used to provide instructions to the driver.

"It would be good if it could show you the picture of the corner where you need to turn… Because it tells you to turn to the right in 200 yards but you do not know how far is that, especially if there are a couple of opportunities to turn relatively close to each other"
Da. Respondent in driving simulator

Connectivity & Software updates: The proposals made to improve the connectivity of the device to the network included the capability to download maps in order the GPS to work in a larger number of locations and the inclusion of an on-board AI such as *Siri* (Bosker, 2013) or *Alexa* (Green, 2017).

"Update the maps and roads automatically so it always recognise the place where you are instead of telling you "you are out of the road on the map I am showing you".
Al. Respondent in isolated room

Customised experience: The ideas collected in relation to customising the user experience ranged from driving monitoring and suggesting alternative destinations, to tracking nearby friends and notifying the driver about their presence.

"I would like it to be like Trip Advisor so it could show me information about stores, places, you know… Ratings or prices in my area"
Ab. Respondent in isolated room

Lastly, it was summarised the number of independent improvement ideas which was extracted from the transcripts of the interviews in each of the two study conditions (Table 20).

	Isolated Room	Driving Simulator	Both Contexts	Total
Navigation Instructions	2	5	7	14
Connectivity & Software Updates	1	2	7	10
Customised Experience	3	9	4	16

TABLE 20: NUMBER OF IMPROVEMENT IDEAS EXTRACTED BY THE CODERS IN EACH CONTEXT

In regards to the saturation, previous literature suggested that four main approaches can be undertaken for its study (Saunders, et al., 2018). These approaches aim to estimate from different perspectives based on data collected, whether further data collection is necessary or not. The approaches most frequently used to analyse saturation are the 'theoretical saturation', 'inductive thematic saturation', 'a priori thematic saturation' and 'data saturation'. Accordingly, they relate to the grounded theory methodology, to the emergence of new codes or themes, to the degree to which identified codes or themes are exemplified in the data, and to the degree to which new data repeat what already was expressed in previous data (Saunders, et al., 2018). In this study, only three main categories were developed by the coders and improvement ideas belonging to all these three categories were identified in the first interview. Therefore, in order to estimate the amount of interviews required to reach saturation it was decided to follow the 'data saturation' approach. To that end, saturation was conceived as a cumulative process which took place as improvement ideas were collected from the data. In this case, 33 of the 40 ideas were collected in the first 15 interviews (Figure 31). This suggests that even though emergent perspectives could be found during any interview, conducting 15-16 participants would be an efficient approach in terms of data saturation to explore key improvement ideas.

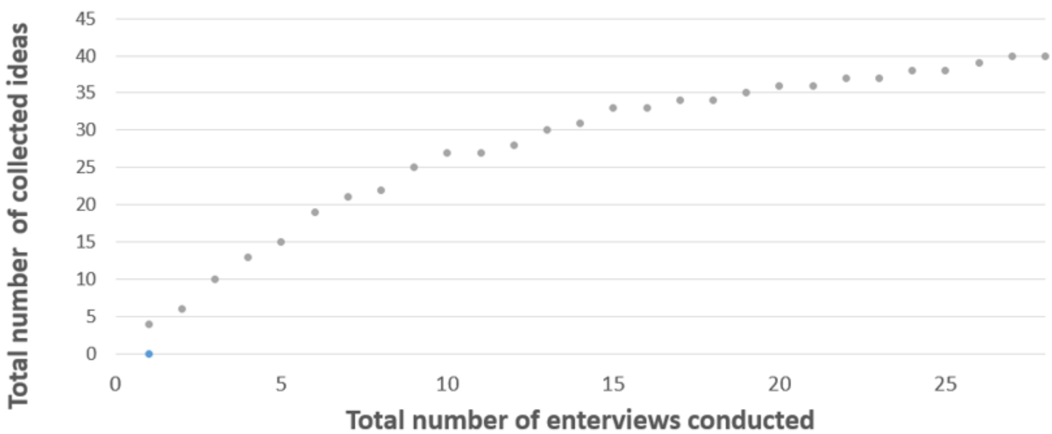


FIGURE 31: DATA SATURATION OBSERVED IN THE THEMATIC ANALYSIS OF STUDY 3

6.4.3 The effect of driving on the creativity

Hypothesis 3: The in-context interview provides more valuable information than the interview from an isolated room in terms of creative achievement. This hypothesis was supported. The professionals selected to take part in the expert panel were encouraged to provide their own definitions for Creativity and a sample of their suggestions is presented next:

"Creativity is a set of cognitive processes through which new and surprising ideas are obtained. That is, they extend the problem-solving or the planning of tasks beyond what is provoked by the immediate circumstances, beyond the obvious and beyond common sense."
JM, Psychologist

Capacity to "spot" a problem in the first place and then resolve it by generating a range of possible solutions and evaluating them to arrive at the optimal one."
VG, Designer

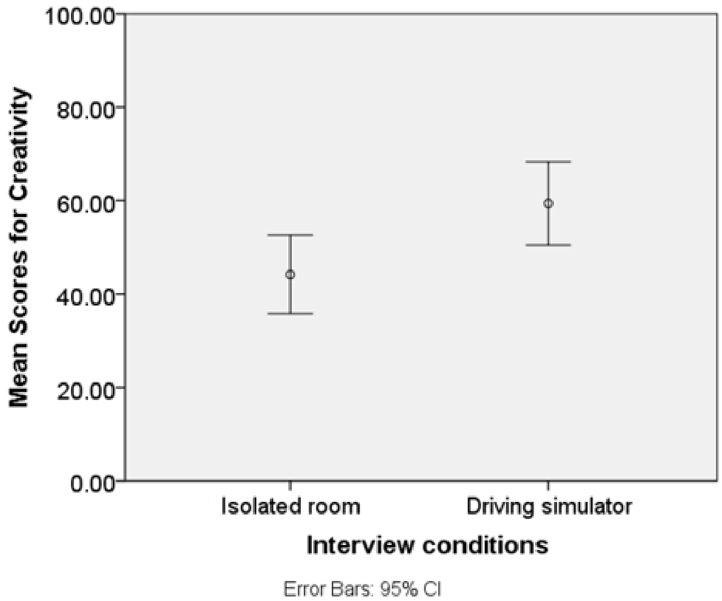
"Creativity involves thinking which is abstract and to some degree new. A creative idea is one which involves some new element, or some missing element, with respect to an accepted idea or solution. To be creative, I do not think that the idea or artefact in question can be highly specific. Some degree of generality, vagueness or looseness of metaphor is required. The human response of "surprise" at the time of the first contact with the idea or artefact is a good indication that there is some degree of creativity."
JG, Researcher

Besides, the expert panel was requested to specify the criteria they required for the assessment of an idea as highly creative. The concepts which the expert panel associated with highly creative answers included: Elaboration, originality, novelty, positive thinking, surprise, and abstractness. The sentences evaluated by the expert panel were the answers provided to the question "If you were to summarise your experience with the navigation tools with a newspaper headline or the title of a movie, what would it be?" To provide an insight into the different answers and conditions in which these were collected, the evaluation of these experts was summarised in a score list (Table 21).

Answers evaluated in terms of creativity	Score (%)	Isolated Room	Driving Simulator
A great power takes a great responsibility	86.3	X	
Lifesaver	82.7		X
My salvation	77.4		X
Your friendly virtual co-pilot	73.8		X
SAT NAV saves the day!	71.4		X
All the maps in your hand	69.6		X
Google Maps plans your weekends	66.7		X
SAT NAV, the navigation system that does not answer back	61.9		X
A way to get lost	61.3		X
Try not to get lost	51.8		X
Long trip in the middle of the night to get to the Grand Canyon	59.5	X	
Take me home	50.6		X
Love-Hate relationship with the GPS	49.4		X
The future of navigation	49.4	X	
An annoying voice in your car helping you to get lost	46.4		X
The navigator makes my life easy	44.6	X	
Playing catch up with navigation systems	44.0	X	
Useful but only beforehand	41.7	X	
Efficient and practical	41.7	X	
Technology made your path easier and did not work later	41.7	X	
First, learn it by yourself, then use it	41.1	X	
Lost	39.9	X	
Accurate software but annoying hardware	39.3		X
Useless navigation	36.9	X	
My hard experience with the GPS	36.3	X	
Useful but the voice is annoying	30.4	X	
Not a very intuitive system	25.0	X	
Travel guide to getting you from A to B	29.2		X

TABLE 21: ANSWERS SORTED BY THE EXPERT PANEL FROM MOST CREATIVE TO LEAST CREATIVE FOR STUDY 3

There was a statistically significant difference between the creativity of the answers while participants were at the isolated room and the creativity of the answers while participants were driving ($t(26) = 2.681$, $p = 0.013$; $P = 0.733$). The interview answers while participants were in an isolated room ($M = 44.179$; $SD = 14.558$) were scored as less creative ($M = 59.393$; $SD = 15.456$) than the answers collected while participants were driving (Figure 32).



	Scores for Creativity	
Interview Conditions	**Mean**	**SD**
Isolated room	44.179	14.558
Driving simulator	59.393	15.456

FIGURE 32: MEANS AND STANDARD DEVIATIONS FOR SCORED CREATIVITY DURING STUDY 3

6.5 Discussion

Based on the results found through the data analyses, four issues were highlighted:

Firstly, participants showed more involvement in the interview while driving than when sitting in an isolated room. This can be argued not only based on the number of words they spoke but also based on the amounts of words spoken by the interviewer in both conditions. The interviewer pronounced a mean of 531 words (SD = 95) during interviews with participants in the driving simulator, whereas he only spoke a mean of 481 words (SD = 121) in the isolated room conditions. Although this difference was not significant, the fact that participants in the driving simulator pronounced a significantly greater number of words (M = 880; SD = 285) than participants in an isolated room (M = 586; SD = 205) suggests that in terms of dominance, the interior of the automobile had an effect on drivers which was described in previous literature (Irvine, 2011). Recent research argued the road type in which the automobile is located to have an impact on the verbal fluency of the drivers when they are interviewed while driving (Giuliano, Germak, and Giacomin, 2017). The results collected from the discourse analysis aligned with such research, suggesting that the physical location in which the interview was conducted had a significant effect on its outcomes. Based on this, it appears reasonable to declare that the in-context interview conducted in the driving simulator provided richer information than the interview in the isolated room in terms of quantity of discourse.

Regarding the variety of the vocabulary, in-context interview also provided greater results than the interview in the isolated room. This can be associated with respondents either providing more detail in their justifications or covering a wider range of topics in their discourses. As discussed in section 1.4, according to the theory of priming (Kahneman, 2011; Hauptmann and Karni, 2002) participants located in environments in which memories or ideas were previously generated are more likely to retrieve such information than participants located in different environments to those (Radvansky, Tamplin, and Krawietz, 2010). Thus, participants holding a steering wheel during the interview may have referred to issues that could not have been considered otherwise. In this study and based on the results of the discourse analysis, it can be argued that in-context interviewing provided richer information in terms of discourse variety and therefore, that priming affected the outcomes of the interview.

On the other hand, the thematic coding did not reveal substantial differences which suggested automotive habitats to provide the environment necessary to potentially stimulate long-term memory in order to ease the retrieval of old ideas. The coders collected a total of 40 ideas to improve the navigation system classified them in 3 main categories. The fact that the number of final categories agreed by the coders is so reduced led these categories to involve general definitions and therefore, ambiguities when assigning the ideas to those categories. For instance, if the minimum percentage of agreement chosen was lower than 90% (i.e. from 70% to 80%), more specific categories would have been defined, potentially leading to a difference between the topics raised in the two interview conditions. Nevertheless, by combining these results with the statistical analysis made on the discourse it is reasonable to state is that the participants who were interviewed in the driving simulator did provide more ideas, and explained them with a greater level of detail, although they did not cover more themes than participants who were interviewed in the isolated room.

Lastly, the definitions separately provided by the members of the expert panel for creativity as well as the criteria they used to rank the answers did not differ to the proposals found in the literature (Said-Metwaly, et al., 2017), which suggests the expert panel was appropriately selected. Furthermore, the results suggested that the interior of the automobile composed a suitable environment for creative achievement (Figure 32). The in-context interview collected richer information than the interview in the isolated room in terms of creativity. In this case, it can be theorized that the automotive environment helped drivers to generate and develop concepts in a reduced amount of time, similarly to the cases in which the priming effect is involved (see section 1.4 for further detail). These results also supported recent literature in which it was advocated that the collection of greater amounts of information sometimes correlate with the collection of more creative ideas (Pedersen, 2019).

6.6 Limitations

Similarly to the case in the previous chapters, the inclusion of a driving simulator to reproduce the interior of the automobile involved some inherent consequences. Even though these tools provide a set of stimuli that can help to achieve the goals for a specific study, driving simulators have been argued to present physical, perceptual and behavioural fidelity limitations which sometimes affect the perception and performance of the drivers (Bella, 2014). On top of that, it is worth noting that when operating the driving simulator, the drivers did not have to follow any specific route. This could have reduced the difficulty of answering the questions while driving, potentially leading to obtaining different results if the tests were undertaken under real driving conditions, where drivers knew their destination and had to navigate accordingly.

It is also worth noting that speaking more words or using a wider vocabulary does not always correlate with the exchange of more information. Despite section 1.6 discussed that more quantity and variety of information was assumed to be good for the designers, the inclusion of more words and vocabulary in absolute terms does not always correlate with more information. In Information Theory, the concept of 'entropy' is applied to measure the extent to which a number of words contain diverse characters. This is due to the association between diversity of vocabulary and the richness of the message (Pierce, 1980). For instance, a participant in the driving simulator could say the same sentence few times or repeat words such as '*like*', '*well*' or '*yes*' repeatedly throughout all the interview for being interrupted by the traffic, and still provide more words than a participant in an isolated room who is not repeating himself. However, the main researcher did not notice a difference in terms of information richness between both interview conditions. Thus, although alternative discourse analysis methods such as Gunning's Fog Index or the Flesch-Kincaid Grade Level based on the count of syllables could provide similar results to the word count and variety including information entropy (Ott and Hardie, 2007), none of them were applied to the study described in this chapter.

In regards to the thematic analysis, due to the complexities inherent to the process of measure and quantify improvement ideas, the first two coders collected pieces of raw text from the interview transcripts and combined them to create a list of improvement points. Thus, the documents received by the other coders included the sentences written by the first two coders, involving inevitably researcher bias. Therefore, although coding checks were performed to ensure an external agreement in the categories defined to cluster the topics of interest covered by participants, these categories can be biased by the first two coders. Lastly and also regarding this analysis, the results were classified in three general categories and improvement ideas started saturating from the first 10-12 interviews. Therefore, increased sample size could potentially provide greater insight into the main concerns raised by the respondents interviewed in both environments. However, these perspectives can be included to the general categories during the coding process, hindering the comparison between the perspectives collected in the two study conditions.

Lastly, as shown in section 2.7.3 the concept of "Creativity" has not been proven yet to be reliably measurable due to the lack of consensus in its definition. This fact leads to a lack of validation in the outcomes of creativity-related research, obstructing possible comparisons between results of independent investigations. In the case of the present study, a consensual assessment technique (CAT) based on the knowledge of an expert panel was applied for being the most suitable approach to analyse content in the automotive content. Since the 'successful' application of such instrument has been argued to strongly rely on the selection criteria for the panel of experts, a literature review was performed in regards to research techniques involving expert panels (Said-Metwaly, et al., 2017). Although the guidelines suggested by authors in Collective Intelligence and the Delphi Method (Origgi, 2018;

Surowiecki, 2004; Williams and Webb, 1994) were followed to select the members for the expert panel, the results may present some difficulties to be compared to those potentially collected in other studies.

6.7 Conclusion

The motivation of the study discussed in this chapter was to determine the possible benefits of implementing real-time remote contextual inquiry between automotive designers and automobile drivers. To that end, the participants of the study were interviewed while driving or staying in an isolated room and the transcripts of the interviews were subsequently analysed in order to compare their answers in both conditions. Subsequently, the value of the information was analysed in terms of quantity and variety of vocabulary based on discourse analysis, in terms of the themes covered based on an inductive approach, and in terms of creative achievement, according to a panel of experts.

The results of these analyses showed that participants interviewed while driving used a significantly greater number and variety of words to answer the questions, in a similar time span than participants interviewed from an isolated room. On the other hand, interviewees in both conditions covered the same themes during the tests. In regards to creative achievement, the answers collected from participants while driving were reported by the panel of experts as significantly more creative than those collected from participants in an isolated room.

These results suggest that implementing contextual inquiry remotely while the respondents are operating an automobile may lead to an enhanced exchange of information in terms of quantity, variety and creativity. However, a driving simulator can never replicate all the complexities of a real-driving environment and this led to the need for studying if the interview developed for the study described in this chapter can provide similar results when applied within a real-driving environment.

7. Study 4: Exploring the Possible Consequences of Conducting Real-Time Remote Contextual Inquiry with Drivers

7.1 Introduction

As described in Chapters 1, 2 and 3, this research aimed to investigate the applicability of real-time remote contextual inquiry between automotive designers and automobile drivers. In turn, it was proposed to explore the communication hardware and channel requirements for the collection of real-time information from drivers, the possible benefits of real-time remote contextual inquiry for the collection of valuable information, and the possible consequences of this approach toward drivers' emotions to assess potential links of these to their road safety (i.e. declined attention to the road, road rage, etc.). Accordingly, *communication hardware* and *channel* requirements were analysed in Chapters 4 and 5, whereas the possible *benefits* of real-time remote contextual inquiry were discussed in Chapter 6. Therefore, the following step to complete this research addressed the investigation of possible effects of real-time contextual inquiry sessions on drivers' emotions under realistic driving conditions.

The studies described in Chapters 4 and 5, and 6 involved simulated driving conditions and as described in section 3.4, driving simulators have been criticised for not replicating the driving environment realistically. Specifically, it has been argued that whereas driving simulators offer a fully controllable environment in which data is cheap to collect, their use frequently involves limited physical, perceptual and behavioural fidelity (Bella, 2014; Winter, Leeuwen, and Happee, 2012). This may, for instance, limit research outcomes due to hazards not being seriously considered by drivers and leading unrealistic driving behaviour. Thus, research projects which include driving simulator studies often follow those by on-road studies to validate results or further investigate in a real-world setting (Weber, 2017). Besides, conducting real-time contextual inquiry sessions while drivers are operating an automobile in the real world may involve safety-related consequences for the drivers. Previous research highlighted the effects of phone and passenger interaction on drivers' behaviour (Oviedo-Trespalacios et al., 2016; Ross et al., 2016; Rhodes, Pivik, and Sutton, 2015). On the one hand, researchers suggested that phone conversing, texting or reading may lead drivers to experience higher cognitive loads and compensating behaviours such as decreasing driving speed or decreasing speech production (Oviedo-Trespalacios et al. 2016, 2017). On the other hand, it has been argued that interaction with passengers influences driving behaviour in different manners (Scott-Parker, 2017). Some examples of this include the encouragement of specific driving behaviours such as speeding or red-light running (Ross et al., 2016), or the induction of affective states which disrupt perception such as anger or sadness, often leading to increased speeds or inattention (Rhodes, Pivik, and Sutton, 2015; Jallais, Gabaude, and Paire-ficout, 2014). Thus, due to the possible limitations in the previous simulator studies combined with the limited literature describing possible safety-related consequences of implementing real-time contextual inquiry sessions with automobile drivers, it was decided to address the last experimental section of this research in a real driving environment.

Furthermore, among the possible effects of implementing real-time contextual inquiry sessions in a real driving environment, previous literature highlighted the importance of the affective state of the driver (Gkatzidou, Giacomin, and Skrypchuk, 2016). Affect is a complex concept that is typically related to three constructs and that is closely related to safety in automobiles. These constructs are emotions, feelings and moods (Jeon, 2015). On the one hand, emotions generally refer to physiological responses of the brain and body, whereas feelings can be considered as the experiential evolution of those emotions. On the other hand, the mood is typically studied as an affective state involving less intense but with more persistent physiological responses (Forgas, 2002; Damasio, 2001). Further research advocated the affective state to be closely linked to decision making, problem-solving and creative thinking (Kaufmann, 2003). To be specific, positive affect has been associated with the enhancement creative processes, whereas negative affect has been associated with the enhancement of analytic processes (Jallais, Gabaude, and Paire-ficout, 2014; Isen, 2001). In the automotive context, the element contributing to the affective state of the drivers that have been most frequently studied is the emotions, for being the source of the most intense physiological responses (Jeon, 2015). Therefore, emotions were proposed to be monitored to create a basic understanding of the affective state of the driver during on-road remote collaborations and assess possible safety-related consequences for the drivers.

In summary, based on previous criticism to driving simulators and the limited literature discussing the effects of real-time remote contextual inquiry on drivers' affective state, it was decided to confirm whether the results collected in the driving simulator and discussed in Chapter 6 were replicable under real driving conditions and to explore possible effects of real-time contextual inquiry on drivers' emotions. Therefore, it was conducted a study in which a group of participants was monitored and interviewed while they were operating an automobile in real driving conditions. Subsequently, the results were compared to those collected in the driving simulator and shown in section 6.4. Thus, the data collected was analysed to complete the response to the question *'What are the benefits of contextual inquiry when it is conducted remotely while the driver is operating the automobile?'* which was partially answered in section 6.5 under simulated driving conditions, and to answer the question *'What is the effect that real-time remote contextual inquiry has on drivers' emotions?'*

7.2 Aim

To answer the proposed research questions, it was developed a study composed of two main objectives. Firstly, this study aimed to confirm whether the results collected in the driving simulator can be replicated under real driving conditions (i.e. word count, word variety, creative achievement, etc.). To that end, it was followed a deductive approach which involved data collection in one experimental condition. Such experimental condition involved interviewing participants while they were driving a real automobile. Subsequently, the data which was collected through those interviews were compared with the data which was collected in study 3 and which involved participants operating a driving simulator. Specifically, the comparison between these two driving conditions was limited to the data collection instruments which provided significant results in Chapter 6 for efficiency reasons. These instruments were discourse and creativity analysis. Secondly, this study aimed to create a basic understanding of the affective state of the driver during real-time remote contextual inquiry sessions and assess possible safety-related consequences for the drivers. To that end, the emotions of the participants were monitored during the interviews and while they were not involved in the interview.

To address the research questions the experiment discussed in the following sections was designed to accept/reject three research hypotheses:

i. *Real-time remote contextual inquiry sessions applied under real driving conditions offer similar results to those collected in the driving simulator in terms of discourse quantity and variety.*
ii. *Real-time remote contextual inquiry sessions applied under real driving conditions offer similar results to those collected in the driving simulator in terms of creative achievement.*
iii. *Real-time remote contextual inquiry sessions applied under real driving conditions affect the emotions of automobile drivers.*

7.3 Methodology

During the study, all the participants were individually interviewed while they were driving an automobile. These participants were different from those interviewed in study 3 to avoid learning effects, and two independent variables were investigated:

The first independent variable was the *driving conditions* and refer to the physical environment in which the participants were sitting *while they were interviewed*. Specifically, these study conditions were two – (i) Driving simulator or (ii) Real automobile. Study 3 provided the results for the interviews in the driving simulator conditions (see section 6.4). Therefore the next sections include **only the explanation of the methodology for the real automobile conditions** as well as the comparison of its results with those collected previously in the driving simulator.

The second independent variable was *the type of human interaction* which participants experienced *during the whole study*. As discussed in section 1.4, the literature supports that positive affect enhances cognitive processes which are associated with creative thinking (Kaufmann, 2003; Isen, 2001), whereas negative affect has been argued to enhance cognitive processes which favour analytic thinking (Jallais, et al., 2014). Moreover, recent literature suggested that human interaction is one of the main sources of positive emotions inside automobiles (Weber et al, 2018). However, studies which recently investigated the emotions experienced by automobile drivers tended to focus on possible triggers of negative emotions or the effects of other specific elements such as traffic flow or road type (Weber, et al., 2019). This leads to limited empiric data regarding the different manners in which human interaction may affect drivers' emotions (Scott-Parker, 2017). Therefore, to explore the possible influence contextual inquiry sessions on respondents' while they were driving, it was decided to compare their emotions while they were interviewed with their emotions while they were naturally interacting with a passenger. Thus, it was observed the type of human interaction in which the participants were involved during the study through two study conditions – (i) Passenger interaction or (ii) Interview interaction. The first of these study conditions referred to natural or non-controlled interaction with a passenger in the back seat of the automobile where the participant was travelling, whereas the second of these referred to the interaction with the researcher while a real-time remote contextual inquiry session was conducted.

7.3.1 Measurement instruments

Following the logic described in section 6.3.1, all the interviews were recorded and transcribed manually by the main researcher in full, including expressions. The voice recorder used to record the dialogues was the "*Easy Voice Recorder*" app installed in a *Motorola Moto G*. The transcriptions were subsequently analysed to address the research hypotheses described in section 7.2. Besides, the strategies to analyse the outcomes of the interview were selected to compare the data between studies using shared variables. Accordingly, the selected analysis strategies were discourse and creativity and these approaches were prioritised for providing significant results in study 3. The Thematic analysis was excluded from this study for data saturation reasons. As described in section 6.4.2, data saturation refers to the cumulative process frequently used to assess whether collecting more data is necessary. In this research, study 3 revealed that after conducting 15 interviews 33 of the 40 improvement ideas were collected. This suggests that the remaining 13 provided only 7 new ideas, resulting in less efficient than the previous interviews for the collection of improvement ideas. On the other hand, the script used for the interview conducted in this study was the same used for study 3. Thus for an efficient praxis, thematic analysis was not considered in this study. On the other hand, the data collection strategy selected to investigate the affective state of the drivers was based on their emotions. This decision was made for being these, according to previous literature, the source of the most intense physiological responses which can be measured among the available affective state metrics (Jeon, 2015).

The following paragraphs include further detail regarding the data collection processes and data analysis strategies proposed to answer the research questions proposed for this study:

Discourse analysis. Similarly to the discourse analysis performed in chapter 6, this analysis was performed using two automatic tools called "*WordSmith Tools 7.0" and "NVivo 12 Pro"*. The first of these instruments was used to generate the tables used to analyse the data and the second of them was selected to generate the diagrams used to summarise the data. Their selection was based on the suggestions found in the literature discussing discourse analysis (Baker, 2006). The quantitative analysis was composed by the *total number of words* spoken by respondents, *word variety* (number of unique words which occur in each dialogue), *word frequencies* (number of times that the most frequent words occur in each study condition), *relative word frequencies* (number of times that specific words occur in the message referred to the total number of words included in the full message) and the length of the interview in *minutes*, (time since the interviewer started pronouncing the first question to the instant when the respondents stopped providing the last answer).

Creativity analysis. The instrument selected was the Consensual Assessment Technique (Amabile, 1982) and it was applied following principles of the Delphi Method for the selection of the expert panel (Skulmoski, Hartman, and Krahn, 2007). These techniques are based on the judgement of creativity by the hand of a 'qualified' panel of experts (see Appendix F.4). The participants collaborating for the evaluation of creativity in the answers were the same individuals selected for study 3 due to the similarities found between their definitions for creativity and the definitions for creativity found in the literature review and discussed in section 2.6.3. For further detail regarding the criteria to select the members of the expert panel, see section 6.3.1.

Emotion Analysis. The approach selected to measure the affective state of the participants was through their emotions and to be more specific, through the use of Facial Expression

Analysis (FEA) combined with a computer-vision algorithm (see section 2.5.2 for further information). This selection was due to FEA solutions to offer a low-intrusive solution to track emotions in real-time and background research supporting its use on the road (Weber et al., 2018; Krosschell, 2017). The tool used for the FEA was called Affdex Affectiva and it provided scores from 0 to 100 for each basic emotion, where the number represented the probability of the face being tracked to match the internal database of the software, which included more than 6.5 million samples (Krosschell, 2017). This tool automatically applied a median correction of the last three face samples to reduce the effect of noise and anomalies. In terms of accuracy, literature supporting the application of FEA for the measurement of the emotions of automobile drivers advocated for the use of thresholds ranging between the 50 and 70 of probability to have a positive detection (Weber, 2017). besides, specific facial movements such as lip press, inner brow raise or brow furrow have been suggested to contribute to the detection of more complex emotions (i.e. displeasure, concentration, etc.). However, in this study, it was aimed to maintain the analysis as simple as possible. Therefore, the threshold selected to consider that emotion was positively detected was 90 to reduce the possibility of collecting false positives (Krosschell, 2017), and the amount of information measured was limited to the six basic emotions. Specifically, the six basic emotions considered were '*Anger*', '*Disgust*', '*Fear*', '*Joy*', '*Sadness*' and '*Surprise*' and these were selected for including the minimum amount of affective information required to create an emotion assessment (Weber et al., 2018; Ekman and Friesen, 1971). The approach proposed to analyse those emotions followed the suggestions found in recent literature, therefore considering three elements: (1) *Number of times each emotion was detected* (also referred to as emotion quantity), (2) *duration of such emotion in milliseconds* (also referred to as emotion intensity), and (3) *emotion detected per minute* (also referred to as emotion frequency) (Weber et al., 2019; Weber et al., 2018). This strategy was selected to provide results which could offer different perspectives on how real-time remote contextual inquiry sessions affected the emotions of the participants and which could be compared with previous research.

On the other hand, the emotions of the participants were recorded through the cameras and analysed by version 7.1 of software called 'iMotions' which included the Affdex Affectiva tool previously described and was installed at one Microsoft Surface Pro 4 inside the automobile

(Krosschell, 2017). This Surface had an Intel Core i7-6650U processor of 2.2 GHz, 16 GB of RAM and a 64-bit Operative System. All the information collected by the cameras, in addition to the outcomes of the Facial Expression Analysis software and CAN bus data (i.e. break pressure, speed, steering wheel position, etc.) was processed by a dedicated software called 'Fusion' and developed by SBG Sports Software for this research. Such software gathered all the information previously described and sent it through a Virtual Private Network (VPN) to a computer located in a control room as suggested by the literature (Figure 33).

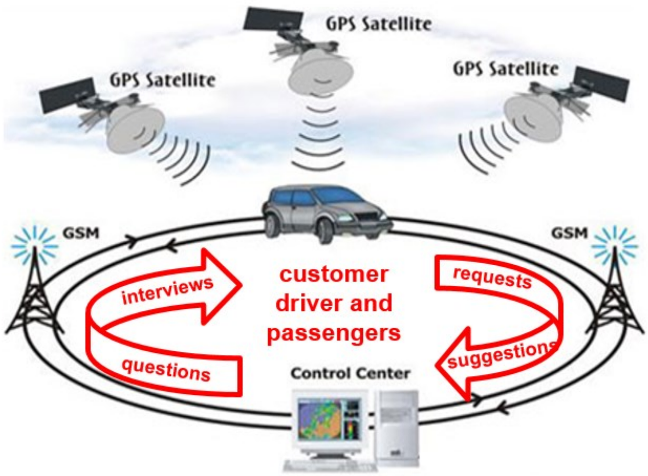


FIGURE 33: NETWORK ARCHITECTURE (GKATZIDOU, GIACOMIN, AND SKRYPCHUK, 2016)

The sources of information recorded during this experiment were the six basic emotions, automobile speed (miles per hour), throttle (% of pedal pressure), brake (% of pedal pressure), engine speed (revolutions per minute), the steering wheel position (degrees) and videos of the exterior of the automobile facing the front of the bonnet, the interior of the automobile facing the participant and the interior of the automobile facing the dashboard (Figure 34). To conclude the description of the elements involved in the collection of data, it is worth noting the characteristics of the space where the designer was located while she was remotely interviewing the participants (Figure 35). Such space was referred to as the control room and it was equipped with a computer which included a Windows 7 Enterprise 64-bit Operative System with an Intel Core i7-4790 processor of 3.6 GHz and 8 GB of RAM. The 'Fusion' Software was installed in the computer and it allowed receiving with a maximum delay of 6 seconds the information collected and processed inside the automobile.

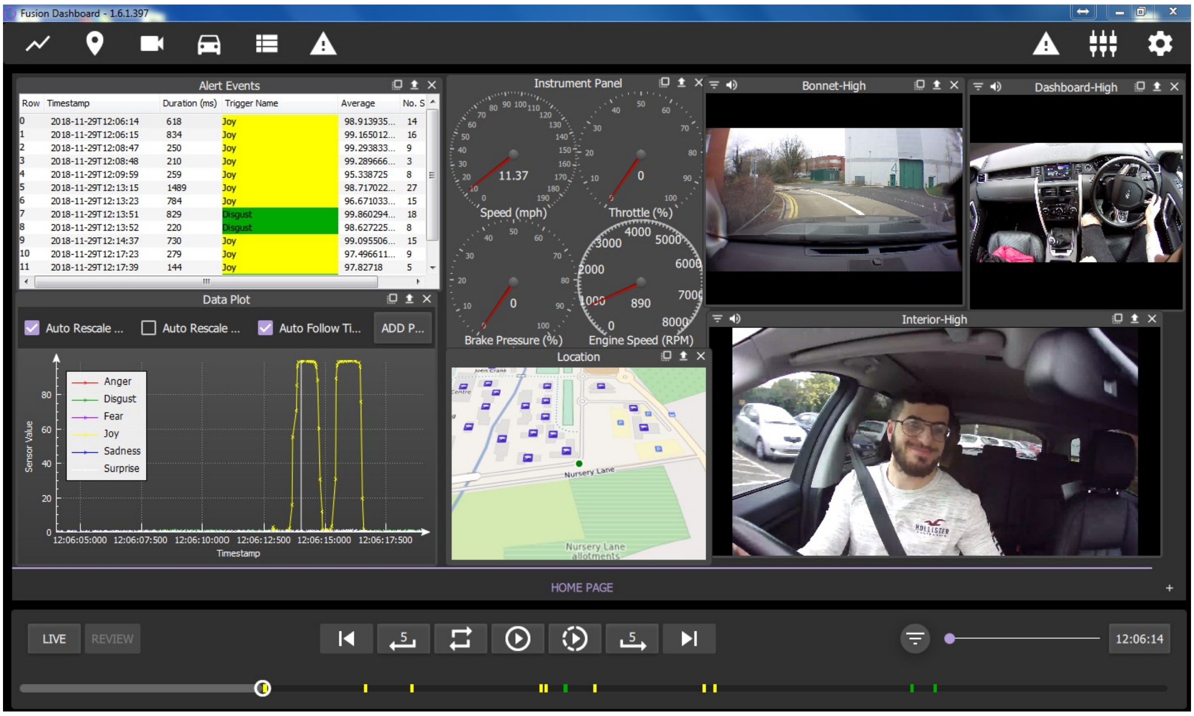


FIGURE 34: SAMPLE OF THE INFORMATION STREAMED BY THE ON-BOARD EQUIPMENT AND MONITORED AT THE CONTROL ROOM

FIGURE 35: LAYOUT OF THE CONTROL ROOM USED FOR STUDY 4

7.3.2 Stimulus materials

The interview. To ease the comparison of the outcomes of this study to the results obtained in Chapter 6, the main topic for discussion through the interview was the same used in such section: the In-Vehicle Navigation System. Accordingly, the structure of the interview was based on Strachan's 5 Processes Framework (Strachan, 2007), the wording of the questions was optimised according to the suggestions made by Foddy (1993), and the objectives of the questions matched the goals proposed by the verbal version of the Torrance Test of Creative Thinking (Torrance, 2008). For further detail regarding the contents of the interview, see section 6.3.2 (for the full script of the interview see Appendix G.3). Participants were encouraged to drive freely without having to follow any specific route as proposed in Chapter 6 to reduce the mental effort required to answer the questions while the respondents were driving (Grier, 2016).

The automobile. The automobile used was a Land Rover Discovery Sport SE eD4 150PS (Figure 36) and which was provided by Jaguar Land Rover for the duration of the study. This automobile was insured by Brunel University for its students and staff members. The automobile counted on manual transmission and a 2.0L 4-cylinder diesel engine. This automobile was also equipped with 3 IP cameras (KNC model HDi47 with a video resolution of 1920 x 1080 pixels and 30 frames per second) pointing respectively towards the front side of the bonnet, the dashboard including the steering wheel and the interior of the automobile focusing on the seats (Figure 34). These cameras were connected to a Microsoft Surface Pro 4 with an Intel Core i7-6650U processor of 2.2 GHz, 16 GB of RAM and a 64-bit Operative System to record and process the video streams. Information regarding the sensors of the automobile was collected from the Controller Area Network of the automobile (CAN data onwards) by three Raspberry Pi's 3, which transferred the data to the Microsoft Surface via USB. The information collected from the CAN data included the speed of the automobile, throttle, brake pressure on the pedal, engine speed in revolutions per minute (RPM) and GPS location. The Microsoft Surface was supervised by one of the researchers who travelled with the participants in the passenger seat and also connected to a Modem to stream the data to the control room where the interviewer was located.

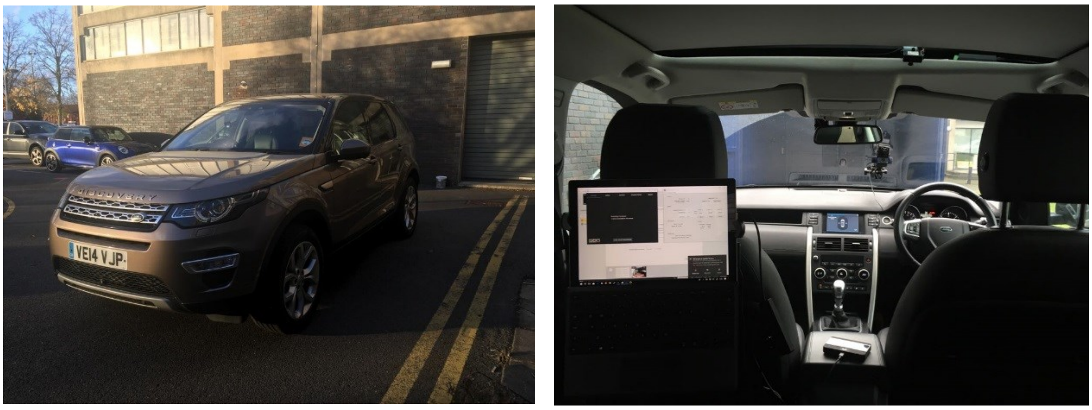


FIGURE 36: EXTERIOR AND INTERIOR OF THE AUTOMOBILE USED FOR STUDY 4

7.3.3 Participants and recruitment

The minimum of participants required to be interviewed in this experiment was fixed to 14 to match the sample size under the driving simulator conditions collected in study 3. For the recruitment of automobile drivers, participants mainly Brunel staff and students were prioritised for insurance-related reasons. Regarding the evaluation of creativity in the ideas, the selected panel of experts was composed of the same 6 members used in study 3.

A total of 17 participants (9 male and 8 female) took part in the study. However, in 3 of them, the emotions data was not recorded and their data was not considered for the analyses proposed. This leaves a total of 14 participants (7 male and 7 female) to compose the sample size. The data collected from these participants were compared to the data collected from the participants who successfully took part in study 3 under the driving simulator conditions (composed of 14 respondents interviewed while operating a driving simulator). Each participant was interviewed only once to reduce learning effects, making participants of previous studies not eligible for the experiment included in this chapter. Both samples (real automobile and driving simulator conditions) were composed of 50% male and 50% female participants. The combination of these two samples had an average age of 25 (SD = 5) with a range of 20-42 years old and an average of 6 years of experience driving (SD = 5) with a range of 1-25 years holding the driving license.

The selection of participants, as well as all stages of the tests, were performed under Brunel University's full ethics approval and in compliance with the pertinent ethics policy (see

Appendix E). As part of such process, all participants were informed about the goals of the experiment (see Appendix A) and asked to complete a form agreeing to take part in the study (see Appendix D). Additionally, the candidates for the interview were asked to answer a screening questionnaire to ensure they were eligible and to confirm their identity at the beginning of the study (see Appendix D).

7.3.4 Study protocol

Due to ethical requirements imposed by Brunel University, two researchers collaborated for the completion of the test by each participant. Both researchers belonged to the design department of Brunel University and had extensive experience working in automotive applications. One of these researchers monitored the study and interviewed the participant remotely from the control room, while the other researcher travelled with the participant for ethical reasons (i.e. in case of an emergency occurs, or in case any participant decided to withdraw to drive the automobile back to the starting point).

Previous to the test the participants were informed regarding the goals of the study and asked to sign a consent form agreeing to take part. Once the engine of the automobile turned on, the cameras started recording video (inside and outside the automobile) and audio (inside the automobile only). All the participants received a brief introduction in regards to the controls of the automobile, and asked to drive over that period to help them become familiar with the automobile controls and to ensure they were suitable to complete the study in full. During such period the participants were checked to be wearing the seatbelt and were encouraged to notify when they felt comfortable with the automobile controls and ready to start the study. Such a process typically took between 2 and 5 minutes.

The telephone of the researcher travelling with the participant was synchronised with the hands-free tool of the automobile and the researcher from the control room started the interview by calling to such number while the participant was driving. All the interviews started when the participants were approximately at the same geographical location (20 seconds after the automobile crossed the gate of the University).

The participants were encouraged to drive freely without any predefined destination to reduce the stress caused by multitasking while being interviewed due to cognitive affordances (Datcu, Lukosch, and Lukosch, 2013; Kahneman, 2011; Ma and Kaber, 2006; Baren and IJsselstejin, 2004). Once the telephone call started, they were asked a few introductory questions and informed again about the goals of the interview previous to address the main topic of the conversation (see Appendix G.3).

After each test, the researcher offered the participant a voucher for £15 as a token of appreciation. Once all the participants taking part in the study completed the test, the interviews were transcribed and subsequently analysed. The participants collaborating as experts for the evaluation panel took part as exactly as done for study 3 and described in Chapter 6.

7.4 Results

Before addressing the research hypotheses, two preliminary examinations were conducted to create a basic understanding of the ethnographic nature of the data collected.

The first of these observations involved the evaluation of sample homogeneity in terms of frequency of use for In-Vehicle Navigation Tools and automobiles, and such evaluation was based on two chi-square tests. The result of the first chi-square test ($\chi^2(2) = 0.624$, $p = 0.732$) revealed that there were no significant differences between the frequencies in which participants advocated to use IVNS. Therefore, the sample was considered homogeneous in terms of IVNS use frequency. In total, 46% of the respondents ($n = 13$) tended to use a navigation tool multiple times every week, 29% of the participants ($n = 8$) confessed that they used it at least once every month and the remaining 25% of the interviewees ($n = 7$) mentioned that they only used these tools in rare occasions which take place every few months (Figure 37). Regarding the use of specific navigation tools, 36% of the participants ($n = 10$) provided their answers focusing on the IVNS whereas 64% of the respondents ($n = 18$) preferred to use phone apps and therefore to answer the questions based on their experience with them. On the other hand and in terms of automobile usage, a second chi-square test ($\chi^2(2) = 1.591$, $p = 0.451$) revealed that there were not significant differences between the frequencies in which participants advocated to drive. Therefore, the sample was considered homogeneous in terms of driving frequency. In this case, 43% of the participants used to drive a minimum of once a week (n = 12), 18% of them used to drive once every month (n = 5) and the remaining 39% declared that they used to drive less than one time per month. The main reason behind such last declaration was that those participants did not own an automobile in the country where the interview took place (n = 11).

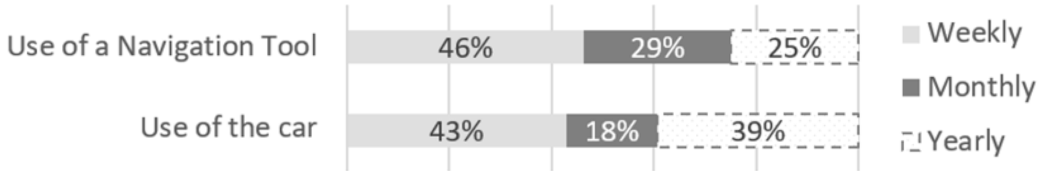
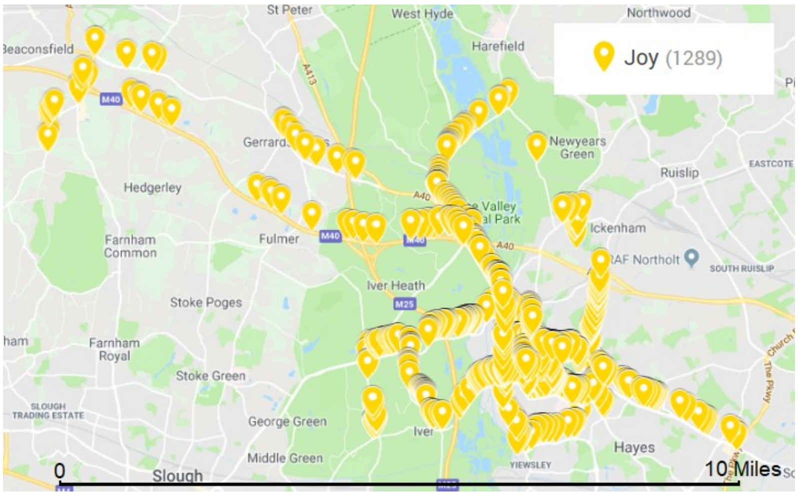
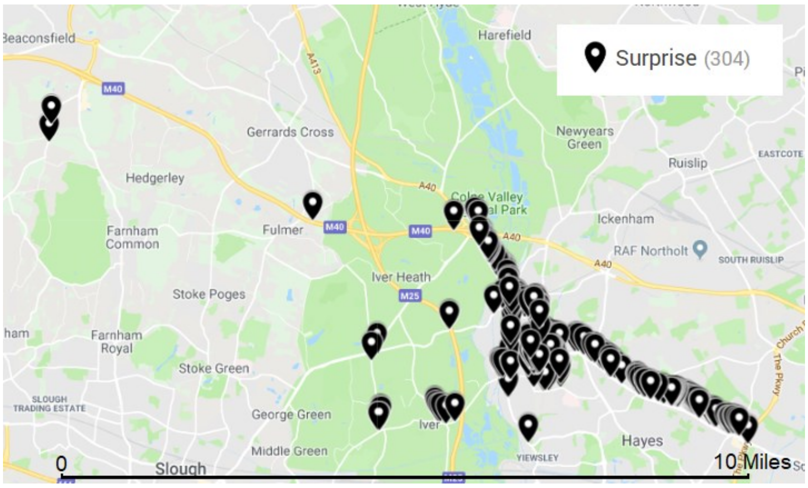


FIGURE 37: REPORTED FREQUENCY OF USAGE FOR AUTOMOBILES AND NAVIGATION TOOLS IN STUDY 4

The second observation involved a descriptive summary of the data collected in terms of emotions and environmental conditions in which those conditions were recorded. Specifically, a total of 1809 emotional responses were recorded during the study. These responses were measured over a period of 474.03 minutes and lasted for a total of 29.60 minutes. The participants generated 1120 of these responses while they were interviewed in a total period of 242.53 minutes and lasted for 16.35 minutes, whereas the other 689 emotional responses were detected in the remaining period of 231.50 minutes and lasted for 13.25 minutes. To create a basic understanding of the environment surrounding those emotions, it was recorded the location in which those emotions were detected (Figure 38). Besides, the automotive environment has been typically studied from a varied range of perspectives (Jeon, 2015; Weng and Meng, 2012). As described in sections 4.3.2, 5.3.2 and 6.3.2, the elements describing the driving scenarios used across this research included road types, light conditions, weather and traffic density. In this study, the road types covered during the tests included urban roads, highways and country roads which extended across an area of approximately 23 square miles. The routes described by all the participants started and finished at the Wilfred Brown car park of Brunel University of London. All these tests took place between the 9:00 am and 4:00 pm to ensure that they were conducted under daylight conditions. The weather varied between sunny, cloudy or with light rain. Lastly, the traffic density varied between studies and tended to range from low to medium densities (i.e. only two participants whose tests took place specifically at mid-day were considered to be involved in high traffic density for being repeatedly caught in traffic jams).





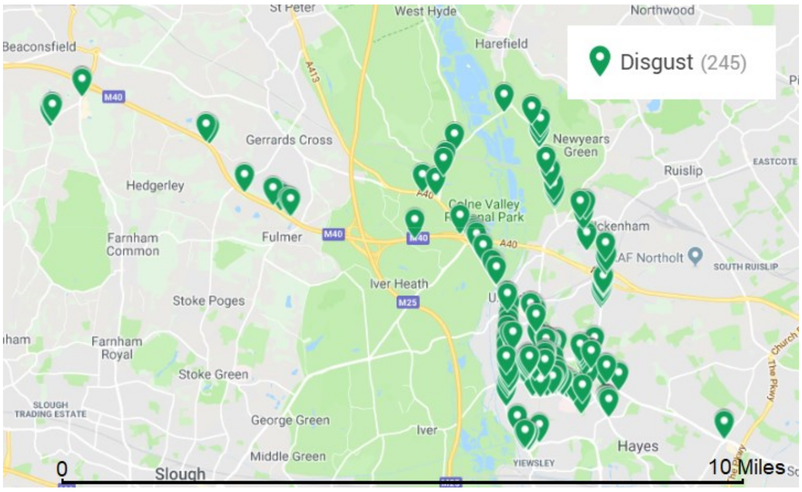


FIGURE 38: GEOGRAPHIC DISTRIBUTION OF THE THREE EMOTIONS MOST FREQUENTLY DETECTED DURING STUDY 4: JOY, SURPRISE AND DISGUST

For the resolution of the hypotheses included in section 7.2 three procedures were followed in correlation to the instruments described in section 6.3.1.

Discourse Analysis: The statistical analysis performed for the discourse analysis followed the same procedure applied for the data analysis of Chapter 6 and described in more detail in section 6.4. Such strategy was composed of 2-tailed independent samples t-tests which aimed to analysed variables such as the number of spoken words, the variety of vocabulary used, or length of the interview were analysed in a single test. Moreover, it was decided to calculate the statistical power of the t-test with $\alpha = 0.05$ to provide more solid conclusions from the study. This decision was made upon the relatively reduced size of the sample (28 participants who were divided into two groups of 14).

Creativity Analysis: The same six experts who collaborated in study 3 were asked again to provide their definition for Creativity as well as a suggestion to measure such construct in ideas (see Appendix F.3). Additionally, they received a list with the answers of the simulator and real-automobile drivers to the question "*If you were to write a newspaper headline to summarise your experience with navigation systems what would it be?*" randomly sorted. These experts were then instructed to sort these ideas by order of creativity according to their previously defined criteria. Following the procedure proposed in study 3 for Creativity evaluation and described in section 6.4, the answers were scored as creative depending on their position in the rankings created by the experts. Subsequently, the analytic hierarchy process was applied to the rankings to explore statistically significant differences between the titles collected in both conditions (Saaty, 2008).

Then, a 2-tailed independent samples t-test was conducted to analyse whether the titles collected in both conditions were statistically similar in terms of creativity or not.

Emotion Analysis: The strategy followed to analyse the effect of the real-time contextual inquiry sessions on the emotions experienced by the participants was composed by three parts: firstly, it was conducted a frequencies analysis to explore the number of times which each emotion occurred. This analysis was followed by a chi-square test of independence to assess a possible relationship between interaction type (passenger interaction or interview interaction) and the number of experienced emotions. The threshold selected for statistically significant results was $p < 0.05$ to match conventional practices and the selection of this test was based on the suggestions found in the literature to explore the relationship between two variables which involve nominal data (Lazar, Feng, and Hochheiser, 2017). Secondly, a paired samples t-test was conducted to explore the possible effect of the interaction type on the duration of the emotions in milliseconds. This type of t-test was selected due to the data sample containing within-group quantitative data, being this the emotions of the same participant interacting with the passenger and with the interviewer. Following the logic proposed for the frequency analysis, the confidence interval selected to consider the difference as statistically significant was 95%. Lastly, a paired samples t-test was conducted to explore the effect of the interaction type on the average quantity of emotions which was experienced per minute. This type of t-test was also selected due to the data sample containing within-group quantitative data. Power analysis was not included in the emotions analyses due to the sample size (N = 1809 emotional responses) being significantly higher than the sample size in previous studies (i.e. N = 28 participants).

The validation of the hypotheses proposed in section 7.2 is summarised next (Table 22).

Independent Variable	Dependent Variable	Null Hypothesis
Driving Conditions	Word count and variety	**Rejected**
	Creativity	Accepted
Human Interaction Type	Six basic emotions	Accepted

TABLE 22: SUMMARY OF THE HYPOTHESES VALIDATION FOR STUDY 4

7.4.1 The effect of driving in the real world on the information collected

Hypothesis 1: Real-time remote contextual inquiry sessions applied under real driving conditions offer similar results to those collected in the driving simulator in terms of discourse quantity and variety. This hypothesis was not supported.

There was a statistically significant difference between real-time remote contextual inquiry under real driving conditions and real-time remote contextual inquiry under simulated driving conditions in terms of the total number of spoken words by both interviewer and respondent: $t(26) = 6.844$, $p = 0.000$; Observed Power = 1.000. The interviews performed while the respondents were driving the real automobile involved a larger amount of total spoken words (M = 2372; SD = 431) than interviews performed while the participants were operating the driving simulator (M = 1375; SD = 333). Moreover, the respondents who answered the questions from the real automobile provided more valuable information in terms of the number of words (M = 1316; SD = 431) than those who were interviewed in the driving simulator (M = 880; SD =285). Such difference was also statistically significant: $t(26) = 3.153$, $p = 0.004$; Power = 0.859. Accordingly, the interviewer pronounced a statistically greater number of words ($t(26) = 11.165$, $p = 0.000$; P = 1.000) when interviewing respondents in the real automobile (M = 1056, SD = 144) than when interviewing respondents in the driving simulator (M = 495, SD = 121).

In regards to the variety of the vocabulary employed by participants in both conditions, the real-time remote contextual inquiry sessions in the real automobile generated more valuable information in terms of varied vocabulary (M = 320 different words used per interview; SD = 58 words) than the real-time remote contextual inquiry sessions in the driving simulator (M = 249 different words used per interview; SD = 52 words). According to independent samples t-test, such difference was statistically significant ($t(26) = 3.411$, $p = 0.002$; P = 0.907).

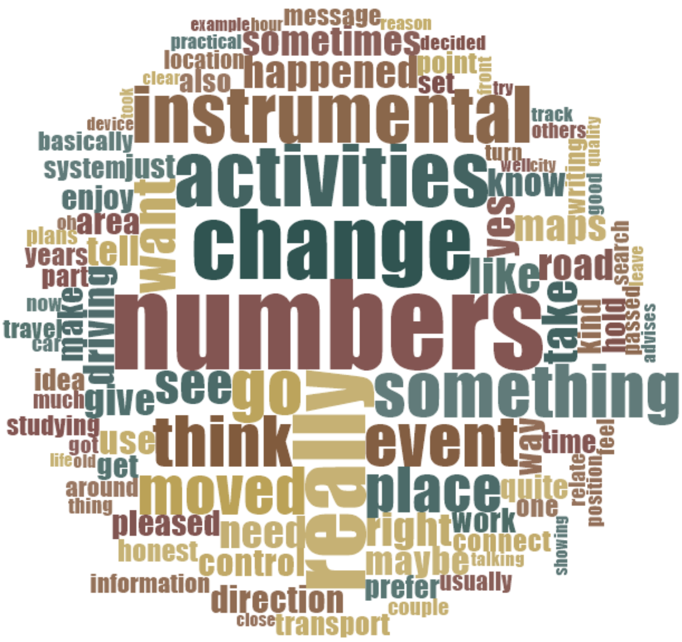
In terms of word frequency (Table 23 and Figure 39), it was analysed the most used nouns for both conditions, as well as the number of times that they occurred in total (N), and the percentage of times that they were used compared to the total number of words used in each condition (%) similarly to the case discussed in section 6.4.1. Again, the words in *cursive* are those not located within the 15 most frequent words in the two experimental conditions.

Driving Simulator			Real Automobile		
Word	N	%	Word	N	%
Car	58	0.47	Car	86	0.48
Navigation	43	0.35	Time	52	0.29
GPS	*42*	*0.34*	Google	42	0.23
Time	41	0.33	Maps	39	0.22
Maps	39	0.32	Road	38	0.21
Places	*37*	*0.3*	*Waze*	*38*	*0.21*
Example	*35*	*0.28*	*Route*	*34*	*0.19*
Google	35	0.28	Way	33	0.18
Place	*28*	*0.23*	*Phone*	*29*	*0.15*
Way	23	0.19	*Traffic*	*29*	*0.15*
Years	*23*	*0.19*	*Thing*	*24*	*0.12*
System	*22*	*0.18*	*Exit*	*23*	*0.11*
Map	*20*	*0.16*	Navigation	23	0.11
Road	18	0.14	*Times*	*23*	*0.11*
Day	*18*	*0.14*	*Roads*	*22*	*0.1*

TABLE 23: SUMMARY OF THE 15 MOST FREQUENTLY SPOKEN NOUNS IN BOTH CONDITIONS OF STUDY 4

In this case, 7 of the 15 words most frequently used differed in both conditions, which can be associated with different approaches to address the interview. For instance, respondents in the driving simulator described their experience through the use of more general terms (i.e. places, example, system, years, etc.), whereas respondents in the real automobile used more specific terms (i.e. traffic, phone, exit, roads, etc.). Further discussion regarding these differences will be included in section 7.5.1. Alternatively, aiming to create a more general insight in regards to the content of the interviews, two word clouds (Figure 39) were generated through the use of the option "generalised concepts" of "NVivo 12 Pro" (see section 6.4.1 for further detail). Words with greater sizes correlate in these diagrams with concepts more frequently referred in each study condition (i.e. numbers, change, activities, etc.). However, words referring to more specific issues were less frequently mentioned and can be found with smaller sizes. These words were typically not shared in both conditions (i.e. Waze, parents, work, etc.), which suggests that respondents covered the same topics and they used different vocabularies to express their opinions.

WORD CLOUD FOR SIMULATED DRIVING CONDITIONS



WORD CLOUD FOR REAL DRIVING CONDITIONS

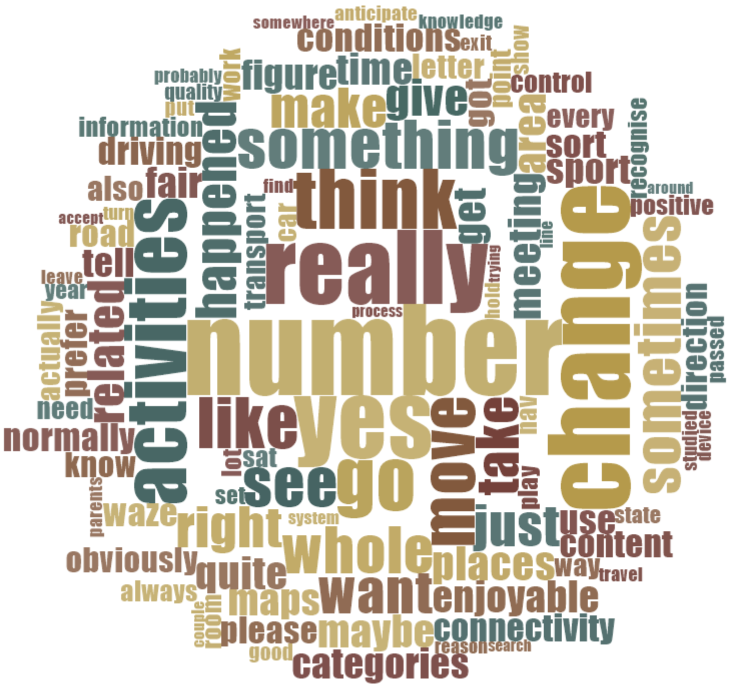


FIGURE 39: WORD CLOUDS FOR THE MOST FREQUENT LEXICAL WORDS OF BOTH CONDITIONS IN STUDY 4

On the other hand, the interviews performed while the participants were driving the real automobile lasted for a longer period (M = 930.21, SD = 132.67) than interviews taking place while respondents were operating the driving simulator (M = 552.21, SD = 163.81). The difference between these two conditions was significant: $t(26) = 6.709$, $p = 0.000$; $P = 1.000$.

Interview length was expressed in seconds to match the practices described for study 3 and therefore, it measured from the instant in which the interviewer started asking the first question to the moment in which the respondent stopped answering the last question.

From the combination of the word quantity analysis and the interview length analysis, an additional independent samples t-test was conducted to create a basic estimate of the verbal fluency of the participants in both conditions (Baker, 2006). Respondents interviewed while driving the real automobile pronounced a statistically similar number of words per minute (M = 85, SD = 22) than participants who were interviewed while operating the driving simulator (M = 96, SD = 14). Such a difference was statistically not significant ($t(26) = 1.566$, $p = 0.130$), suggesting that participants showed similar verbal fluencies in both conditions. Lastly, the most relevant values analysed for the assessment of the effect of the driving environment on the discourse were summarised (Table 24).

		Participant words	Participant words variety	Seconds	Minutes	Participant words per minute
Driving simulator	MEAN	880	249	552	9'12"	96
	SD	285	52	164	2'44"	14
Real automobile	MEAN	1316	320	930	15’07”	85
	SD	431	58	133	2’01”	22

TABLE 24: MEAN AND STANDARD DEVIATION FOR WORDS SPOKEN BY PARTICIPANTS AND INTERVIEW LENGTHS IN STUDY 4

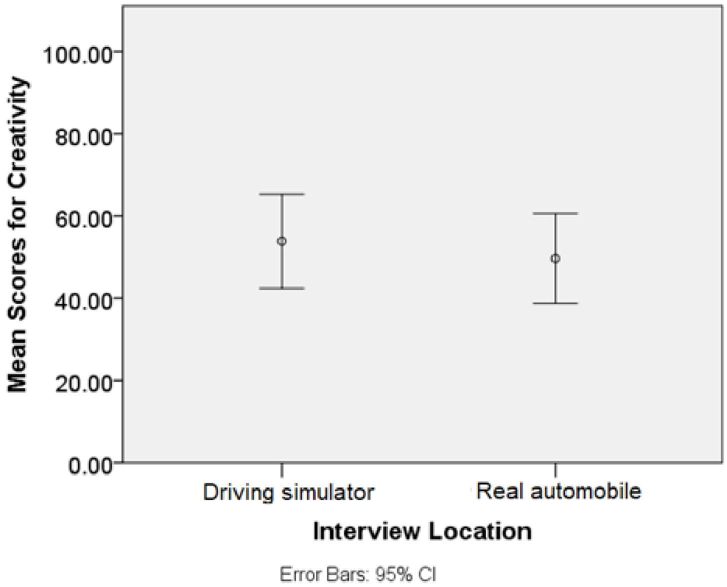
Hypothesis 2: Real-time remote contextual inquiry sessions applied under real driving conditions offer similar results to those collected in the driving simulator in terms of creative achievement. This hypothesis was supported.

As discussed in section 7.3.4, the expert panel used the same criteria employed to sort the ideas in terms of creativity they used in study 3 (see 6.4.3 for further detail). Such criteria consisted of associate more creative ideas with higher degrees of elaboration, originality, novelty, positive thinking, surprise, or abstractness. The sentences evaluated by the expert panel were the answers provided to the same question used in study 3, which states: “If you were to summarise your experience with the navigation tools with a newspaper headline or the title of a movie, what would it be?” To provide an insight into the different answers and conditions in which these were collected, the final list of the answers sorted by the expert panel is shown next (Table 25).

Answers evaluated in terms of creativity	Score (%)	Driving Simulator	Real Automobile
The perfect imperfect wife	80.0		X
SAT NAV saves the day!	77.1	X	
Lifesaver	77.1	X	
Showing the better ways	74.3		X
All the maps in your hand	74.3	X	
My salvation	72.1	X	
Is it all bad?	70.0		X
Your friendly virtual co-pilot	69.3	X	
Take me home	65.7	X	
Saving me when I am lost	62.1		X
A way to get lost	61.4	X	
Gets you where you need to go	57.9		X
Guided on being lost	52.1		X
Google Maps plans your weekends	51.0	X	
The adventure of travelling with Google Maps	51.0		X
Google Maps, making your drive home enjoyable	49.3		X
SAT NAV, the navigation system that does not answer back	45.7	X	
SAT NAVs, making driving better for tomorrow	46.4		X
Try not to get lost	43.6	X	
Waze gets you quicker	42.1		X
Love-Hate relationship with the GPS	40.7	X	
Stressful but useful	38.6		X
Getting around with Google Maps	35.0		X
An annoying voice in your car helping you to get lost	32.1	X	
SAT NAV, disaster or great help?	27.1		X
Travel guide to getting you from A to B	25.0	X	
Accurate software but annoying hardware	19.3	X	
Misleading information of SAT NAVs	10.0		X

TABLE 25: ANSWERS SORTED BY THE EXPERT PANEL FROM MOST CREATIVE TO LEAST CREATIVE FOR STUDY 4

The statistical analysis showed that there was not any statistically significant difference between the creativity of the answers respondents gave in the real automobile and the creativity of the answers respondents gave in the driving simulator ($t(26) = 0.570$, $p = 0.574$). Both numerical and graphic comparisons between these two conditions were summarised (Figure 40).



	Scores for Creativity	
Interview Conditions	**Mean**	**SD**
Driving simulator	53.864	19.849
Real automobile	49.686	18.929

FIGURE 40: MEANS AND STANDARD DEVIATIONS FOR SCORED CREATIVITY DURING STUDY 4

7.4.2 The effect of the real-time remote contextual inquiry on drivers' emotions

Hypothesis 3: Real-time remote contextual inquiry sessions applied under real driving conditions affect the emotions of automobile drivers. This hypothesis was not supported due to the drivers showing statistically similar rates of emotions per minute while they were interacting with the passenger and while they were interacting with the interviewer.

Firstly, a frequency analysis was conducted and its results were summarised (Table 26). Subsequently, the chi-square test of independence suggested that the interaction type affected significantly the number of emotions experienced by the participants ($\chi^2(5) = 18.709$, $p = 0.002$). The number of times each emotion was detected during both interaction types was summarised in a bar chart (Figure 41).

	Passenger Interaction (231 min)		Interview Interaction (242 min)	
	n	Times detected (%)	n	Times detected (%)
Anger	4	0.58	6	0.54
Disgust	84	12.19	161	14.38
Fear	0	0.00	1	0.09
Joy	505	73.29	724	64.64
Sadness	6	0.87	14	1.25
Surprise	90	13.06	214	19.11
Total	689	100	1120	100

TABLE 26: FREQUENCY AND NATURE OF THE EMOTIONS DETECTED DURING STUDY 4

Alternatively, the emotions experienced while the participants were interacting with the passenger (M = 1088; SD = 1805) lasted for longer than the emotions experienced while the participants were interacting with the interviewer (M = 795; SD = 1054). This difference was statistically significant (t (707) = 3.788, p = 0.000) and the duration of each emotion was summarised (Figure 41).

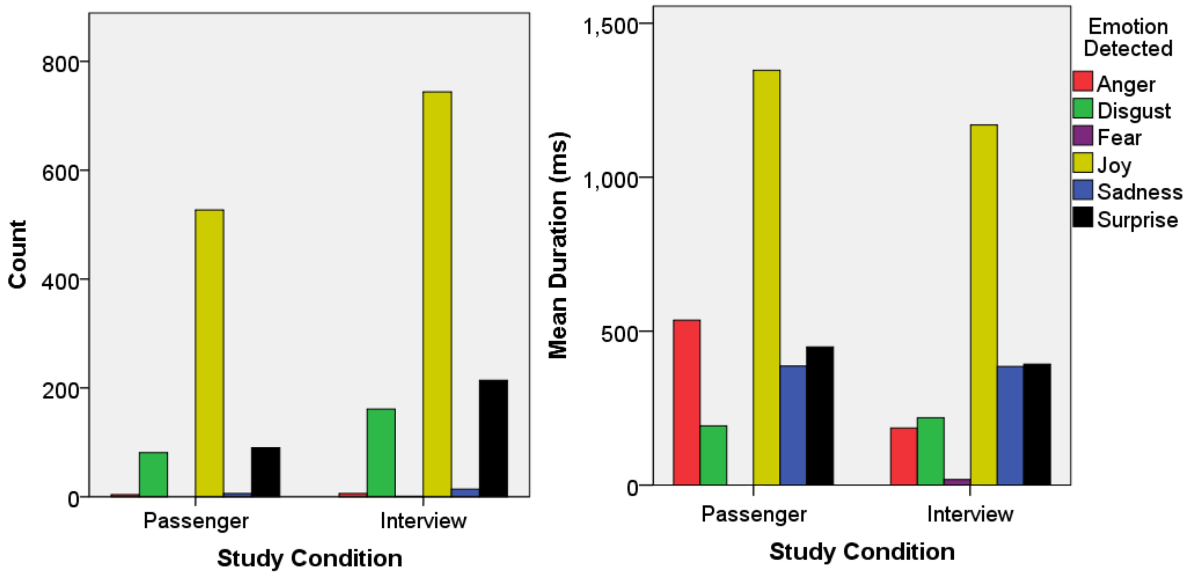


FIGURE 41: SUMMARY OF THE FREQUENCY AND DURATION OF THE EMOTIONS DETECTED DURING STUDY 4

Lastly, the participants showed a lower rate of emotions per minute while they were interacting with the passenger (M = 0.241; SD = 0.211) than while they were interacting with the interviewer (M = 0.322; SD = 0.214). However, this difference was not significant (t (13) = 1.661, p = 0.121). In turn, the results classified in a table by emotion type and the values of such table which were marked with a '*' represent an average of the column in which they were located (Table 27).

	Passenger Interaction (231 min)		**Interview Interaction** (242 min)	
	n per Min	**Time detected (%)**	**n per Min**	**Time detected (%)**
Anger	0.02	1.10	0.02	0.26
Disgust	0.36	3.96	0.66	5.70
Fear	0.00	0.00	0.00	0.00
Joy	2.18	90.37	2.99	85.36
Sadness	0.03	0.16	0.06	0.33
Surprise	0.39	4.41	0.88	8.35
Total	0.24*	100	0.32*	100

TABLE 27: SUMMARY OF THE EMOTIONS DETECTED PER MINUTE DURING STUDY 4

7.5 Discussion

As seen in section 3.4, the use of driving simulators has been widely used for research purposes. However, the outcomes of studies involving such technology have also been criticised for the lack that these pieces of equipment present to fully recreate the real world. In the following, section 7.5.1 analyses the results obtained when conducting real-time remote contextual inquiry sessions under real driving conditions by comparing them to those collected under simulated driving conditions.

On the other hand and as described in section 7.1, human interaction has been argued to significantly affect drivers' emotions (Rhodes, Pivik, and Sutton, 2015; Jallais, Gabaude, and Paire-ficout, 2014). Furthermore, previous literature advocated that emotions affect cognitive resources associated with creative thinking and analytic thinking (Jallais, Gabaude, and Paire-ficout, 2014; Kaufmann, 2003; Isen, 2001). Due to the limited literature investigating the combination of these elements in a real-driving environment, it was decided to explore possible effects of real-time contextual inquiry on drivers' emotions. Therefore, section 7.5.2 includes a discussion of the results obtained from comparing the emotions of the participants while they were interacting with a passenger and while they were interacting with the interviewer.

7.5.1 Observed consequences of driving in the real world

Overall, the data analyses which were conducted and described in section 7.4.1 revealed mixed results, suggesting a partial difference between the influence of the real-driving environment and the simulated-driving environment on drivers' answers to the real-time remote contextual inquiry sessions. Specifically, the outcomes of those analyses led to discuss three different issues: observed consequences of driving in the real world in terms of word quantity, word variety and creative achievement.

Firstly, the total number of spoken words was higher in the real automobile than in the driving simulator (t (26) = 6.844, p = 0.000). Both drivers and interviewer tended to pronounce significantly more quantity of words in the real automobile conditions than in the driving simulator conditions. This difference can be associated with participants driving in a real environment. For instance, the risk of experiencing physical pain in case of an accident was higher in the real automobile than in a driving simulator, leading participants to increase their attention to behave safely in real-driving conditions (Winter, Leeuwen, and Happee, 2012). An example of this effect can be found in the study recently conducted by Semmens et al. (2019) in which they asked 63 drivers to confirm whether it was a good time to start receiving 50 minutes of non-driving related information while they were driving. Such confirmation request was made randomly across a predefined route, and the results showed a high correlation between the closeness of the automobile to junctions and negative responses from the drivers. This suggests that driving across 'hot points' such as junctions or roundabouts may require higher cognitive loads from drivers, leading them to refuse to engage in a secondary task. In this case, such effect may have led drivers to ignore questions made while they were approaching to junctions or roundabouts, requiring the interviewer to repeat those questions and increasing the total number of spoken words, interview length and specifically the researcher's spoken words as shown in the statistical tests described in section 7.4.1.

Furthermore, previous literature suggested that longer questions tend to induce respondents to provide longer answers (Foddy, 1993). Therefore, the significant increase of interviewer's spoken words (t (26) = 11.165, p = 0.000) may have caused drivers to provide longer answers, leading to a significant increase on drivers' spoken words ($t(26) = 3.153$, $p = 0.004$). To explore the change of behaviour that the interviewer had to perform, the ratio of words spoken by the interviewer per word spoken by the drivers was compared. Such ratio was considered as the number of words required to be spoken by the interviewer to receive a single word in response from the drivers. For instance, a ratio of 0.608 means that for every 60.8 words (≈ 61 words) spoken by the interviewer, the participants would answer with 100 words. In turn, these ratios were lower in the driving simulator ($M = 0.608$; $SD = 0.218$) than in the real automobile ($M = 0.873$; $SD = 0.268$). The difference between the two conditions was significant ($t(26) = 2.872$, $p = 0.008$; $P = 0.790$) and it was interpreted as the interviewer tending to lead the conversation significantly more in the real automobile than in the driving simulator. This effect also aligns with previous literature, in which interview dominance was investigated in face-to-face and telephone interviews (Irvine, 2011). Interview dominance refers in this context to the tendency to speak more words than the other member of the interview. For instance, an interview in which the interviewer speaks more words than the respondent would have a dominance skewed towards the interviewer, suggesting that the interviewer tended to lead the conversation (Irvine, 2011). The results of such investigation involved interviewers showing more dominance in telephone conversations than in face-to-face interactions, suggesting that interviews conducted while the respondents can be involved in a secondary task may require interviewers to actively interact with the respondents to maintain their engagement to the conversation.

Secondly, the information was analysed in terms of the variety of vocabulary. Real-time remote contextual inquiry sessions conducted while the participants were in the real automobile also collected a greater variety of words than those conducted while participants were in the driving simulator. This effect was associated with the inherent relationship between the variety of words required to pronounce a message and the length of such message in the number of words (Baker, 2006). To confirm this, ratios of vocabulary divided by total words used by each participant were compared between the two study conditions. These ratios were statistically similar in both conditions ($t(26) = 1.098$, $p = 0.282$), suggesting that participants used new words with the same frequency in both conditions. According to this analysis, more quantity of words may have led participants to use more variety of words.

Therefore, considering the discussion made in the previous paragraphs, it appears reasonable to associate the difficulties of driving in the real world with an increase of the quantity and variety of words which was observed when the real-time contextual inquiry sessions were conducted under real-driving conditions.

Besides, 7 of the 15 most frequently used words were different between the two study conditions (Table 23). This suggests that respondents in the driving simulator described their experience focusing on general terms (i.e. places, example, system, years, etc.), whereas respondents in the real automobile used more specific terms (i.e. traffic, phone, exit, roads, etc.). This aligns with previous literature which associated the use of more specific concepts and shorter sentences when the speaker was involved in higher cognitive demanding tasks (Khawaja, Chen, and Marcus, 2010). Therefore, this was also reflective of the higher cognitive involvement that driving a real automobile required from drivers.

Lastly, the answers provided in the real automobile were statistically similar in terms of creativity according to the expert panel. This suggests that participants driving either across simulated environments or real-world environments were equally creative. Also, as described in section 6.4.3, participants operating driving simulator provided more creative answers than participants in the isolated room while they were not driving. Therefore, the creative outcomes of real-time contextual inquiry sessions which took place while respondents were driving (regardless of being a real automobile or simulator) were considered more creative than the creative outcomes obtained while the respondents were not driving.

In summary, the results described in section 7.4.1 suggested that driving in the real world required drivers to increase their attention to the road for safety reasons, in turn limiting the cognitive resources dedicated to the real-time contextual inquiry sessions. This resulted in increased word quantities, word varieties and longer interview lengths due to the interviewer having to repeat questions. Therefore, these results reinforced the statements found in the literature in regards to the limitations of the driving simulators to accurately recreate realistic environments (Lucas et al., 2020; Winter, Leeuwen, and Happee, 2012; Blana, 1996).

7.5.2 Observed consequences of the real-time remote contextual inquiry sessions

Similarly to the previous section, the data analyses which were conducted to investigate the consequences of the real time-remote contextual inquiry sessions toward drivers' affective state revealed mixed results. Specifically, those analyses addressed three different issues: observed consequences in terms of emotion quantity, emotion intensity and average emotion frequency. Among these issues, previous literature tended to exclusively focus on the average emotion frequency to describe the affective state of the drivers (Weber, 2017). Nevertheless, emotion quantity and emotion intensity were included in this discussion to provide a wider perspective of the driver's affective state.

In terms of emotion quantity, participants showed significantly fewer emotions while they were interacting with the passenger than while they were interacting with the interviewer ($\chi^2(5) = 18.709$, $p = 0.002$). This can be associated with the communication channel supporting the remote interaction. On the one hand, as described in sections 2.5.3 and 5.5, the access to non-verbal information such as body language or facial expressions may significantly affect the outcomes of remote interaction. For instance, previous literature suggested that interaction which occurs face-to-face tends to involve different levels of interruptions, overlaps or pauses than interaction supported by communication channels which do not support non-verbal information such as voice-based conference calls (Halbe, 2011). On the other hand, as described in the previous section, the real-driving conditions introduced some distractions which temporally interrupted the dialogue, leading the interviewer to repeat questions. Thus, the limited access to non-verbal information which the voice-based conference call offered may have supported the distractive effects of the driving environment, leading interviewers to repeat questions and in turn, leading drivers to react more times to the interview. Alternatively, the three basic emotions that were detected most frequently were 'Joy', 'Surprise' and 'Disgust' for both interaction types and the results showed similarities with those found in the literature (Table 28). A recent study explored the most frequent emotions that drivers experience while operating an automobile in the real world concluding that the most frequent of the basic emotions were 'Joy', 'Disgust' and 'Surprise' (Weber et al., 2018). Therefore, driving can be associated with these three basic emotions as they represented more than 90% or registered responses throughout the three driving conditions considered in this discussion.

	No Human Interaction* (440 minutes)		Passenger Interaction (231 minutes)		Interview Interaction (242 minutes)	
	n	Times detected (%)	n	Times detected (%)	n	Times detected (%)
Anger	13	6	4	1	6	1
Disgust	62	28	84	12	161	14
Fear	0	0	0	0	1	0
Joy	77	35	505	73	724	65
Sadness	7	3	6	1	14	1
Surprise	59	27	90	13	214	19
Total	218	100	689	100	1120	100

TABLE 28: COMPARISON OF THE QUANTITY OF BASIC EMOTIONS FOUND IN THE LITERATURE WITH THE TWO CONDITIONS OF STUDY 4 (WEBER, GIACOMIN, MALIZIA, SKRYPCHUK, AND GKATZIDOU, 2018)*

After comparing the results of study 4 with those found in previous literature it is worth noting that participants driving while they were engaged in human interaction experienced significantly more quantity of emotions (involving a total sample of N = 1809 collected across 473 minutes) than participants not engaged in human interaction (involving a total sample of N = 218 collected across 440 minutes). Moreover, human interaction induced higher levels of Joy, reducing levels of Anger and Surprise (Table 28). According to the literature, joy has been typically considered as a positive emotion (Scott-Parker, 2017; Weber, 2017; Ekman and Friesen, 1971). Therefore, it appears reasonable to suggest that regardless of its type, human interaction offered a positive response in drivers' affective state.

In terms of emotional intensity, there was a statistically significant difference between the two study conditions (t (707) = 3.788, p = 0.000), being this intensity higher while the participants were interacting with the passenger (M = 1088; SD = 1805) than while they were interacting with the interviewer (M = 795; SD = 1054). Similarly to the effect described for the number of emotions detected, this difference can be associated with the communication channel. According to Parkinson (2008), face-to-face interactions in which all parties 'share a common agenda', tend to generate more persistent emotions. In this case, the distractive nature of the driving environment was shared by both drivers and passenger, and this may have caused the experienced emotions to last longer. On the other hand, the duration of the two experimental conditions in this study was different. This led to collect emotion data across different periods (passenger interaction data was collected across 231 minutes, whereas interview interaction data was collected across 242 minutes). Since the intensity of the emotions was measured with their duration, this may have possibly led to inaccuracies. Therefore, it was decided to prioritise the average emotion frequency analysis to describe the overall affective state of the participants across the whole study.

Lastly, in terms of average emotion frequency, the participants showed a higher rate of detected emotions per minute while they were being interviewed (M = 0.322; SD = 0.214) than while they were interacting with the passenger (M = 0.241; SD = 0.211). However, this difference was not significant due to the standard deviations of both samples, which suggests that individually the participants were differently prone to provide emotional responses. For instance, the participant who showed less emotional responses provided a total of 20 samples in a period of 17’01” (total average of 0.030 emotions per minute), whereas the participant who showed more of these provided a total of 364 samples in a period of 41’50” (total average of 0.768 emotions per minute). This aligns with previous literature which suggested that using the six basic emotions as a unique approach for FEA to involve significant variations between participants (McDuff, et al., 2016). However, this approach has been also criticised due to these emotions being typically detected once every two minutes and being labelled as scarce (Weber et al., 2018). In this study, a basic emotion was detected every 15.69 seconds (collecting a total of 1809 samples across a total of 473 minutes), which led to consider the six basic emotions as a sufficient source of data to assess the affective state of the drivers. Thus, since the paired samples t-test did not reveal a significant difference between the two interaction types, it was concluded that during the tests real-time remote contextual inquiry evoked to the driver statistically similar emotions to those generated by human interaction with other automobile users.

In summary, despite some differences in the quantity and intensity of the experienced emotions, the average emotion frequency was similar in both study conditions. This suggests that real-time contextual inquiry sessions did not induce drivers to experience emotions which significantly differ to emotions typically experienced when automobile drivers share space with a passenger. Moreover, both of the study conditions led drivers to experience more joy, less disgust and less surprise than only driving according to previous measurements found in the literature. Therefore, drivers' involvement in human interaction was assessed as more relevant toward their emotions than the type of interaction in which they were involved.

7.6 Limitations

In the study described in this current chapter, the interview was conducted by a female researcher to accelerate the process required for participants to trust the interviewer. According to the literature, trust is crucial for the achievement of 'successful' collaboration (Chua, Morris, and Mor, 2012; Nevejan, 2009). Moreover, it has been argued that women are considered more trustworthy than men in non-technical contexts and the female voice has been widely used to provide gender to technology towards Human-Computer Interaction applications (Mou and Xu, 2017; Waytz, Heafner, and Epley, 2014; Buchan, Croson, and Solnick, 2008). However, changing the interviewer who led the interaction somewhat increased uncertainty in the results. Thus, although the increase of the number of words spoken by both of the collaborators was mainly associated with the exchange of a greater amount of useful information, such effect cannot be exclusively assigned to the environment in which the driver was located during the communication.

It is also worth noting that as discussed in section 6.6, the use of a greater number of words or a wider range of vocabulary cannot be always associated with a greater amount of information. For instance, if a participant repeated the same sentence consecutive times changing some words due to traffic distractions, this created a larger variety and count of spoken words, whereas the amount of 'useful' information would remain the same. None of the analyses shown in section 7.4.1 was performed to ensure that such effect was not affecting the results because the main researcher transcribed manually all the interviews (n = 28) and did not find any pattern that was affecting only one of the two interview conditions. However, mentioning this issue can guide future research in case the number or the variety of words was proposed as an instrument to explore richness in verbal interaction. If that was the case and the main researcher did not personally review the original transcripts searching such patters, this effect could be explored through any of the analyses mentioned in section 6.6.

On top of that, participants were aware of the nature of the study and therefore, they were expecting a telephone call while driving. Further research is required to explore if drivers who are not expected to be called while operating the automobile show the same compliance that respondents in this study. Besides, all of the interviews started when participants were located with the automobile at the same physical location, which leads to question if the timing selected to start the conversation is relevant for the outcomes of the conversation. For instance, the length of the interviews took up to 20 minutes and in a real scenario in which an automotive designer is conducting a real-time remote contextual inquiry, there is a possibility of drivers to not spending such amount of time within the automobile in some specific journeys. Thus, the importance of selecting when to start the communication needs to be highlighted.

Regarding the measurement of emotions, previous research argued the exclusive use of the six basic emotions to rely on the affective state assessment to offer limited results due to their significant variations between participants and scarce occurrence (McDuff, et al., 2016; Tian, Takeo, and Cohn, 2001). As described in the previous section, the least affectively responsive participant provided 20 emotion samples, whereas the most affectively responsive participant provided 364. This difference supports the arguments described in the literature. However, since the inclusion of affective analysis in this study was for exploratory purposes, the results collected from the 14 participants can be used in the future as a guideline of which type of affective reactions to expect when an automobile driver is interacting with a designer.

Lastly, it is worth noting that both passenger and interview interaction engaged each participant with two different researchers, which may have affected their affective responses. However, no significant differences were found between these two conditions and for the exploratory purposes of the affective analysis, the aim shown in section 7.2 was achieved.

7.7 Conclusion

The motivation of the study discussed in this chapter was to confirm whether the outcomes obtained in the first application of real-time remote contextual inquiry sessions can be replicated under real driving conditions and to explore the implications of such application towards the emotions of the driver (see chapter 6 for further detail regarding the first implementation of real-time remote contextual inquiry in a driving simulator). Thus, the participants who took part in this study were interviewed and monitored while they were freely driving a real automobile. The interviews were subsequently transcribed and analysed to compare their discourse to those collected in the driving simulator. To that end, the number and variety of words spoken by both participant and interviewer were counted, the length of the interviews was measured in minutes, and the creativity of the answers was scored by a panel of experts. Alternatively, the emotions were monitored and processed in terms of quantity, intensity and average frequency.

In terms of outcomes replication from the driving simulator under real driving conditions, results showed that participants who were operating a real automobile while they were interviewed tended to be less engaged in the conversation than participants who were operating a driving simulator while being interviewed. Despite the participants showed similar verbal fluencies (i.e. words per minute) while they were driving in the driving real world and while they were driving in the simulator, interviews which took place while the participants were driving in the real world lasted for longer than those taking place in the driving simulator. This led to collect a greater number of words from the participants and the interviewer, and this effect was assigned to driving in the real world to influencing drivers' behaviour towards safety. Specifically, being physically on the risk of an accident required a higher level of attention to the road and the participants tended to prioritise the driving task over the interview when they were operating a real automobile. Thus, due to driving-related interruptions, the interviewer was forced to repeat questions to maintain the participants engaged in the interview. Regarding the creativity of the interview outcomes, the answers collected from participants while they were driving a real automobile did not differ statistically to the answers collected from participants in the driving simulator, which had been assessed as significantly more creative than the answers collected in the isolated room in Chapter 6. This suggests the interior of the real automobile to provide a suitable environment for real-time contextual inquiry sessions as conducted in studies 3 and 4.

In terms of the implications of implementing real-time remote contextual inquiry sessions towards the emotions of the drivers, results suggested that the distractive nature of driving in the real world also affected drivers' emotions. The emotion analyses revealed that participants showed significantly more emotions while they were interacting with the interviewer than while they were interacting with the passenger. This was associated with drivers reacting more times to the interview due to the interviewer repeating questions. Alternatively, the remote nature of the contextual inquiry sessions led the drivers to experience significantly shorter emotions during the interview interaction than during the passenger interaction. After combining the data used in those previous analyses, no significant difference was found in the emotions per minute experienced by the drivers in both interactions. This result was assigned to the effects of human interaction on collaborators being more relevant towards their emotions than the content of the interaction itself.

In summary, the results of this study suggested that the interior of real automobiles offer an environment in which real-time contextual inquiry sessions can be effectively implemented to collect customer feedback and creative answers. This is based on the real-driving conditions maintaining the levels of information exchanged under simulated conditions in terms of verbal fluency and creativity. Moreover, the drivers experienced the same emotions while they were being interviewed and while they were interacting with a passenger. This suggests that the possible safety-related consequences of real-time remote contextual inquiry sessions were limited to those associated with driving with a passenger in a natural setting.

8. Conclusions and Future Work

8.1 Introduction

The automotive industry is currently facing an era of rapid evolution, which is partially driven by the development of sophisticated electronics and algorithms. These developments are affecting user behaviour, gradually changing customer experience (Smith, Vardhan, and Cherniavsky, 2017). In order to explore possible implications of this evolution, researchers of the automotive industry currently apply methodologies such as online surveys, telephone interviews and more recently, trend analysis (Audi, 2017; Porsche, 2017; Seat, 2017). These methodologies tend to focus on drivers' opinions, not necessarily capturing how they experience the automobiles. Besides, the methods rely on human long-term memory which is affected by a large list of cognitive processes (Benson, 2016). These processes include the "location updating effect" (Radvansky, Tamplin, and Krawietz, 2010), which refers to a decline in memory when people move from one place to another, and the "fading affect bias" (Walker and Skowronski, 2009), which involves affect associated with negative memories fading faster than affect associated with positive memories. These processes lead to inaccuracies and biases in the data collected from automobile customers (Benson, 2016).

Aiming to improve the situation, researchers increasingly shifted their interest towards the Human-Centred Design approach, which has been recently considered as a form of structured empathy (Giacomin, 2014). In turn, there was an increasing tendency to collaborate with customers for the design of future automobiles (Ramm, et al., 2015). Part of this community focus was on contextual inquiry (Gkatzidou, Giacomin, and Skrypchuk, 2016), which in the automotive context referred to collaborating with drivers while they were inside the automobile. Thus, several cognitive biases including the "location updating effect" or the "fading affect bias" previously described were argued to be reduced.

More recently, researchers started exploring the possibility of connecting designers with users in real-time while they were driving (Martelaro and Ju, 2017; Giuliano, Germak, and Giacomin, 2017). Those researchers advocated for the use of the co-design approach in order to provide carmakers with both ethnographic data and creative ideas generated through contextual inquiry (Gkatzidou, Giacomin, and Skrypchuk, 2016). This research investigated the applicability and possible benefits of connecting automotive designers and automobile drivers while they were driving for a real-time remote collaborative session based on the use of contextual inquiry.

8.2 Addressing the Research Question

In order to investigate the applicability and possible benefits of connecting automotive designers and automobile drivers for a real-time collaborative session, the main research question was proposed in section 1.7 and stated: "**How can real-time remote contextual inquiry be implemented in the automotive context?**"

In turn, this question was divided into four parts to address open questions found in previous literature (Gkatzidou, Giacomin, and Skrypchuk, 2016). As described in section 1.7, the first two of these parts were selected to define the minimum requirements to conduct on-road contextual inquiry sessions, whereas the following parts aimed to separately investigate benefits of those sessions for the collection of valuable information, and possible effects of those sessions on driver's emotions. Subsequently, these new questions were further discussed and answered individually in Chapters 4, 5, 6 and 7. This section summarises the resolution of the four questions selected to answer the research question as well as the respective procedures which were followed to that end.

a) Which apparatus can be installed within the automobile? Which specifications should they have?

This question was addressed through a literature review and a case study in a driving simulator which is discussed in Chapter 4. The literature review aimed to explore suitable communication channels and apparatus to support real-time communication between designer and automobile driver as well as the implications for the drivers of using those. Literature suggested voice-based conference call and video-based conference call to be effective communication channels to support remote collaboration and these methods frequently require the use of screen and speakers as an interface for interaction between collaborators. Therefore, it was decided to analyse the effects of the on-board screen and speaker characteristics on the driver's perception and performance while using them and driving. To that end, a total of 24 participants took part in a study (n = 24) and were asked to perform a set of activities interacting with these apparatus at the same time they were operating the driving simulator. Results showed that an on-board screen can be used to support real-time remote contextual inquiry sessions, whereas a speaker does not significantly affect the driver's perception nor performance. Thus, although limitations of both the simulated environment and the methodology were identified, results provided an insight into the basic effects the characteristics of the communication hardware have on the driver and how they could be selected. Based on this, it was recommended the use of larger screen sizes with higher resolutions to reduce the workload required for driving and multitasking and increase the perception of media quality.

b) What is the optimal method to communicate automobile driver and designer for a real-time remote-collaborative interaction?

This question was addressed through a literature review in telepresence perception and alternative solutions followed by a case study in a driving simulator which is included in Chapter 5. The literature review aimed to create a basic understanding of which elements affect the experience of immersion during remote collaboration and how technology users perceive the virtual presence of their collaboration partners. This review included technologies which create virtual presence and methods to measure the perception of presence in different circumstances such as during interaction with technologies themselves (i.e. androids, computers that seem to be 'alive' or robots), remote interaction among people (i.e. conferencing), or interaction with objects or people generated by technology itself (i.e. driving simulator). Subsequently, it was designed a study to evaluate how the users of these technologies perceived each other while they were collaborating remotely and operating a driving simulator. To that end, a total of 24 participants took part in the study and they were assigned a role among two options: driver (n = 12) or research assistant (n = 12). They were grouped in couples and asked to perform a set of collaborative activities. Results showed that the communication channel was not critically relevant for the closeness in which the interaction partners perceived each other. However, the participants reported the voice conference call to provide enough information from their interaction partner for a 'successful' collaboration. Thus, it was concluded that the voice conference call composed the most efficient communication channel to support remote collaboration in the interior of the automobile.

c) What are the benefits of contextual inquiry when it is conducted remotely while the driver is operating the automobile?

This question involved the most significant findings of the research and it was addressed through a literature review in effective interviewing for creative achievement and two case studies involving interviews which were conducted while the respondents were operating a real automobile, operating a driving simulator or sitting in an isolated room. These studies are included in Chapters 6 and 7. The literature review aimed to help to create a set of questions that in a short period (defined as in between 10 and 15 minutes) could effectively collect customer feedback and creative answers towards the generation of product improvements. Thus, 17 questions were developed to compose a contextual inquiry session and subsequently tested in the three conditions previously described. These questions are summarised in Appendix G.3 and a list of guidelines to create further questions is included in Appendix H.

A total of 42 participants took part in these studies (n = 42) of whom 14 were assigned the isolated room conditions, 14 were assigned the driving simulator conditions and 14 were assigned the real automobile conditions. The first test covered the isolated room and driving simulator conditions, showing that participants operating the driving simulator as a group provided longer, more varied, and more creative answers than participants interviewed in an isolated room. Then, a second study took place to explore whether the outcomes of the driving simulator conditions were similar to the outcomes generated by drivers while they were operating an automobile in real driving conditions. The second study only involved participants in real driving conditions and results showed that as a group, respondents who were driving a real automobile required longer to complete the contextual inquiry session than participants operating the driving simulator. These participants also provided longer and more varied answers, whereas the level of creative achievement remained statistically similar to the level achieved in the driving simulator. Creative achievement was, in both studies, assessed by a panel of experts systematically selected according to the literature guidelines. These results suggest that both simulated and real driving conditions composed a suitable environment for real-time remote collaborative interaction between designer and automobile driver. Additionally, it was concluded that real-time remote contextual inquiry sessions were more beneficial than telephone interviews in terms of the collection of valuable information.

d) What is the effect that real-time remote contextual inquiry has on drivers' emotions?

This question was addressed in Chapter 7 through the case study in which a real automobile was driven by 14 participants (n = 14). In this study, the participants were asked to drive freely while being interviewed and having natural interaction with a passenger in the back seat of the automobile. The period the participants operated the automobile was recorded by three cameras inside the automobile and a Facial Expression Analysis was performed to measure the emotions of the driver during both the interview (labelled as interview interaction in Chapter 7) and the interaction with the passenger (labelled as passenger interaction in Chapter 7). Respondents provided more emotions per minute during the interview interaction than during passenger interaction. However, these results were not statistically significant. This non-significant difference suggests that real-time contextual inquiry sessions in which designers interacted with drivers while they were driving were conducted 'safely' in terms of possible consequences towards drivers' emotions. Lastly, both types of interaction evoked more positive emotions than the activity of driving alone, which suggests that having a companion may have provided a greater influence on emotion than the nature of the companion itself. Thus, it was concluded that real-time remote contextual inquiry sessions did not involve significant consequences toward the driver's emotions.

8.3 Contributions

The central contribution to the field offered by this research was the evaluation of real-time remote contextual inquiry as a research method for the collection of ethnographic information, customer feedback and improvement ideas for the development of new automobile models (see Appendix H). Such evaluation was conducted by means of a systematic literature review which was followed by four separate studies. During this process, a range of outcomes was highlighted as relevant for the field of the research, which was characterised by a limited number of studies involving remote collaboration between designers and automobile users while they were driving (see sections 1.6 and 2.8 for further detail). These outcomes were summarised as follows:

- Evaluation of alternative screen sizes, resolutions and speaker volumes which could be used as communication hardware to support real-time remote collaboration between an automobile and a control room. This provided empirical data which led to prioritise greater screen sizes, higher screen resolutions and higher speaker volumes in the subsequent studies conducted during this research.
- Evaluation of voice-based conference call and video-based conference call as alternative communication channels to support real-time interaction between designers and drivers while the members of this last group were operating an automobile. Such evaluation led to an increased understanding in regards to the relevance of visual cues during remote collaboration and the selection of the voice-based conference call as a recommended communication channel for real-time remote contextual inquiry.
- Increased understanding of the methods which can be used to conduct real-time remote contextual inquiry sessions in automobiles (see Appendix H). This was driven by the development of an interview script which was tested under both simulated and real driving conditions. Those conditions included alternative road types and traffic intensities. The answers collected from 28 interviews included a total of 40 different ideas to improve In-Vehicle Navigation Systems. Such script can be used in future

research to design interviews for the collection of ethnographic information, customer feedback and improvement ideas.

- Increased understanding of human behaviour inside automobiles driven by the collection of empirical data in regards to the workload, perception and emotions of automobile drivers when they are engaged with different activities while driving (i.e. listening to a recorded speech, checking a map shown on the on-board screen, receiving a video-based conference call, interacting with a passenger, etc.).
- Demonstration that the principles to select experts for the application of the Delphi Method can be used to build an expert panel for the Consensual Assessment Technique towards the evaluation of Creativity in small pieces of work such as single sentences.
- Demonstration that the use of FEA can be successfully applied to explore the emotions of automobile drivers under partially controlled circumstances in real driving scenarios.

In summary, this research led to an increased understanding of the methods which can be used to collaborate with customers in the automotive context. The findings of the four studies conducted during the research allowed the development of a set of guidelines to conduct real-time remote contextual inquiry sessions (see Appendix H) and the suggestions collected during studies 3 and 4 provided opportunities to develop new designs based on real-time customer feedback. Thus, the practices of this research can be incorporated into future research methodologies to create a shared understanding of customer experience among designers and automobile drivers and to facilitate idea generation for the development of new models.

8.4 Threats to Validity

The current research found limitations that are recommended to be avoided in the future. These limitations were classified in two main categories, which involved the methodology-related issues and automotive-related issues.

Methodology

The exclusive use of either objective or subjective measurement techniques can lead to drawing conclusions based on a partial insight into the reality. Objective measurement instruments provide results that occasionally differ from the perception of the participants, whereas if the aim of the study is related to user experience, subjective measurement instruments provide of a greater insight into the desires of the drivers.

On top of that, the use of a single instrument to collect data will always involve the limitations inherent to the method. If a secondary measurement technique was used to support the data collection, the limitations of the first instrument could somewhat be compensated. For instance, the use of FEA as a single method to explore the driver's emotions led to a lack of Intensity Indication. Since the software used to perform such analysis (Affectiva Affdex) does not provide any intensity measurement on top of the length of detection, it is recommendable to combine FEA with a physiological measurement tool to specifically report the arousal or intensity for emotion (i.e. Galvanic Skin Response (GSR), Electrocardiogram (ECG)). Further research on the use of the length of an emotional response as a reference for its intensity needs to be performed.

Additionally, the measurement of creativity for research purposes can be a challenge for scholars since no-agreement has yet been reached. The most common practice to address this concept is defining creativity as a multifaceted phenomenon and subsequently, analyse each of the constructs that according to the authors better describe it. However, the consensus has not been reached in regards to which constructs better define creativity. Thus, more work needs to be done on this in order to ease the comparison of results in different contexts.

To conclude with the issues found through the methodology applied in this research, it is worth noting that the transcription of all the interviews conducted during studies 3 and 4 was conducted manually by the main researcher of this investigation, which somewhat affected the timeline of the Autohablab Project (see section 1.5 for further detail). Previous literature discussed the advantages and disadvantages of using automatic tools to translate hours of dialogue into pages of written text (Lazar, Feng, and Hochheiser, 2017). On the one hand, these tools may reduce the time required to edit and analyse data. On the other hand, these tools are also subject to recognition errors which can affect the quality of their output. This might have introduced inaccuracies in the analysis of the data. Therefore, it was decided to avoid the use of transcription automated tools, regardless of the time required to manually conduct the transcriptions. Future research is recommended to consider possible time pressures when deciding the method which will be used to transcribe interviews.

Automotive

The use of a real automobile in this research involved issues such as biases due to the specific automobile used for the study. In order to avoid those biases, future research is suggested to use alternative automobile models during every single study. Additionally, the study involving the real automobile was conducted with the presence of a researcher acting as a passenger for the passenger interaction. To avoid possible biases caused having a single passenger while driving it is suggested in future research to include different numbers of passengers in the automobile. Finally, it is worth noting that the participants were informed prior to the test that they would be interviewed and therefore they expected to receive a telephone call while driving. This may have alienated the outcomes of the interview due to the biased disposition of the participants to being engaged in a collaborative interaction while driving (i.e. in other circumstances the driver can decide not to answer the telephone call). To avoid this issue, it is suggested to conduct more studies in which the drivers are not aware of the potentially incoming telephone call and subsequently evaluate whether a notification needs to be sent prior to the call to notify the automobile drivers that they will be contacted soon (i.e. My name is X and I work for X, I have a couple of questions about your satisfaction with the automobile and I would like to call you in five minutes if that is ok to you).

In summary, further research is recommended to ensure highly reliable results. To that end, studies are suggested to involve a greater number/variety of automobiles, driving conditions, interviewers and participants. On top of that, the inclusion of a co-pilot or passengers in the collaborative interaction can potentially help to generate more creative outcomes. However, the addition of more variables can reduce the statistical power of the results if the study is not rigorously controlled. Therefore, future studies are recommended to involve a single differentiating factor at once (i.e. automobile model, number of participants inside the automobile, etc.).

8.5 Proposed Applications and Future Work

Holistically, the collection of ethnographic data can be used as a complementary activity to ensure innovative technologies such as voice, emotion or gesture recognition systems can be accurately implemented in new automobile models (Manyika, et al., 2013). Thus, carmakers can access to both objective and subjective data from drivers in real-time. For instance, the implementation of the interview questions and guidelines developed throughout the current research can be of special interest for the future design of fully automated automobiles. Recent literature highlighted that automobile drivers are expected to perform in the automotive habitat activities never considered before (Smith, Vardhan, and Cherniavsky, 2017), and the implementation of real-time remote contextual inquiry sessions inside the first automobile prototypes can help designers to find key improvement ideas before self-driving technologies are extended worldwide (Smith, Vardhan, and Cherniavsky, 2017; Cha et al., 2015). In summary, the interview questions and guidelines are suggested to be used to either complement the information collected by on-board technologies or to find key customer concerns and collect possible solutions in regards to a specific topic (see Appendix H).

Since the interview developed throughout this research included questions to retrieve customer feedback and improvement ideas, its employment is not limited to the automotive context. Other technology companies such as the computer, smartphone or television sellers could similarly benefit from this protocol considering they could contact their customers through their devices for collaborative interaction. However, legal restrictions may be applied depending on the specific legal context in which the seller and the driver are located and similar results cannot be ensured in other environments due to the lack of benefits that the dynamic nature of driving has on the automobile drivers as discussed in Chapters 6 and 7. Therefore, more research can be conducted to explore to what extent are the outcomes of the current research applicable to other industries.

On the other hand, the contents of the interview which shapes the real-time remote contextual inquiry sessions can be developed in the future following two main directions:

Develop the technology involved in the application of the protocol: The inclusion of on-board monitoring systems allow the recognition of a set of scenarios in which the users need to be alerted. For instance, a drowsy driver can be recognised by a glace recognition software and the automobile would create an alarm to notify the driver that should stop driving and rest (Jeon, 2015). Thus, monitoring tools such as glace, emotion or gesture recognition can be used to detect possible periods in which the highly useful outcomes of real-time remote contextual inquiry could be achieved and automatically offer to start a voice call between designer and users.

Additionally, voice recognition software could be implemented to automatically transcribe, analyse and store the dialogue. Recent research proposed the use of chatbots to collect live customer feedback and it can be an improvement option if the priority of the specific interaction is the collection of ethnographic data. However, the use of those solutions to replace real-time human interaction and especially in terms of creativity achievement has not provided yet statistically similar outcomes as face-to-face dialogues (Martelaro and Ju, 2017) (Hill, Ford, and Farreras, 2015). This leads to the need for further research to explore the applicability of chatbots for the collection of ethnographic data and creative achievement in the interior of the automobile.

Develop the content of the dialogue for creative achievement or linguistic studies: The current version of the interview includes questions inspired by different design methods such as participatory design, the AEIOU framework, brainstorming, participant observation, design ethnography, design workshops, etc. (Martin and Hanington, 2012). These methods influenced the protocol in the number of questions included in the interview, their wording and the order in which these questions were asked. In future research, all these elements can be modified to explore their individual contribution for creative achievement or to investigate driver's discourse while operating the automobile.

9. Reference List

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Appendix

Appendix A: Information sheets for research participants

Studies 1 and 2.

Information Sheet for Research Participants

You will be given a copy of this information sheet.

A driving simulator study to inform the design of an Automotive Habitat Lab.

We would like to invite you to participate in this research project. It involves a driving simulation study where you can help us design the future in-car technology. Estimated duration: 40 minutes.

What is the study about?
This study involves driving in a fixed car simulator. What this means is that we will ask you to drive a stationary car in the same way you would drive a real car. You will be required to use car's controls (steering wheel, pedals and gearbox) to drive through one scenario that will be displayed on the screen on the wall in front of you. Before the simulation starts and during the driving task, we will ask you to discuss your experience with us.

What do the researchers want to find out? We want to find out how we can design in-car technology to improve your driving experience.

Do I have to take part? No. It is completely up to you whether you take part or not.

What happens to my information?
Information acquired during the course of the user trials will be used solely for the purposes of the research. Personal data from participants will be limited to the consent form, with an ID number allocated to each participant which will then be associated with the study data. No names or personally identifying information will be used outside those directly involved in the collection, transcription and analysis of these data, and the supervision of this; no personally identifying information will appear in internal or external reports and publications. Hard copy consent forms, simulator sickness questionnaire and study sensitive data (such as participants' contact details) will be kept in a locked filing cabinet and will be destroyed once the study has taken place or – if it cannot be scheduled – at the end of the data collection phase. All electronic files which can or may contain personally identifying information will be stored only on the Brunel and/or departmental computer systems. Personally identifying data will be removed and transcriptions anonymised at the earliest available opportunity (e.g. by replacing any names mentioned with pseudonyms). Once transcribed and once the transcription is checked, electronic files will be destroyed. The transcription will therefore not contain any personally identifying information. The lead researcher supervising the various studies within this project has completed the online Health and Safety Research Integrity course.

Why do I have to fill in a health form?
We will ask you to fill in a health form- the purpose of this is only for us to decide whether you are eligible to participate in this study. For reasons of health and safety, if you suffer from any of the conditions that are included in the form, we would exclude you from this study.

Can I find out the results of the study?
Yes. If you would like to be sent a copy of the study report or you have any question/suggestion, please contact the researcher using the email or phone number above.

Can I keep this information sheet?
Yes, this information sheet is for you to keep.

If you have any query, please do not hesitate to contact the main researcher Daniel de la Flor.

If you have any complaint, please contact Professor Hua Zhao, Chair of the Research Ethics Committee for the College of Engineering, Design and Physical Sciences.

All data will be collected and stored in accordance with the Data Protection Act 1998.
This activity has been approved by the Research Ethics Committee as of 12th July 2016.

Researcher details: Daniel de la Flor Aceituno *Daniel.DeLaFlorAceituno@brunel.ac.uk*

Study 3 and study 4 for participants collaborating as 'Experts'.

Information Sheet for Research Participants

You will be given a copy of this information sheet.

A driving simulator study to inform the design of an Automotive Habitat Lab.

We would like to invite you to participate in this research project. It involves the evaluation of creativity in a set of interviews conducted while people were using a driving simulator. Estimated duration: 15 minutes.

What is the study about?

This study involves collaboration with two types of participants: interviewees and experts. The interviewees will be asked a set of questions regarding navigation systems in cars and requested to provide ideas to summarise their experience with such tools. Half of the interviews will take place conditions A and the other half will take place in conditions B in order to study the influence of the driving task on the answers. After collecting the information from interviewees, the conversations will be transcribed and sent to the experts for further analysis.

The analysis of the transcriptions will be structured based on the Delphi technique, which is an iterative multistage process designed to transform opinion into group consensus. This means that we will ask you for your opinion about what creativity is, how to measure it and how creative are the ideas given by the interviewees. We will then combine your feedback with the other experts' opinions and come back to you, with a fusion of definitions for creativity, criteria for its evaluation and a ranking of creative ideas based on the opinion of all the experts involved. Once you receive this summary we would like to give you the opportunity to change anything you want in your initial feedback and we will repeat this process with all the experts until a consensus have been reached.

In sum, you have been selected as an expert due to your experience in either psychology, design or the automotive industry, which makes your opinion very valuable for the purposes of this research. Thus, we would like to hear what you understand for creativity and your personal criteria to assess creativity in some ideas we will share with you. To conclude the analysis, we would like you to rank the ideas we gave you from the least creative to the most creative according to your criteria. Feedback with the opinion of other experts will be provided afterwards.

What do the researchers want to find out? We want to find out if car drivers report more creative ideas while driving than when asked in an empty room.

Do I have to take part? No. It is completely up to you whether you take part or not.

What happens to my information?

Information acquired during the course of the user trials will be used solely for the purposes of the research. Personal data from participants will be limited to the consent form, with an ID number allocated to each participant which will then be associated with the study data. No names or personally identifying information will be used outside those directly involved in the collection, transcription and analysis of these data, and the supervision of this; no personally identifying information will appear in internal or external reports and publications. Hard copy consent forms, simulator sickness questionnaire and study sensitive data (such as participants' contact details) will be kept in a locked filing cabinet and will be destroyed once the study has taken place or – if it cannot be scheduled – at the end of the data collection phase. All electronic files which can or may contain information related to this experiment will be stored only on the Brunel and/or departmental computer systems, therefore, protected with a password. Personally identifying data will be removed and transcriptions anonymised at the earliest available opportunity (e.g. by replacing any names mentioned with pseudonyms). Once transcribed and once the transcription is checked, electronic files will be destroyed. The transcription will therefore not contain any personally identifying information. The lead researcher supervising the various studies within this project has completed the online Health and Safety Research Integrity course.

Can I find out the results of the study?
Yes. If you would like to be sent a copy of the study report or you have any question/suggestion, please contact the researcher using the email or phone number above.

Can I keep this information sheet?
Yes, this information sheet is for you to keep.

If you have any query, please do not hesitate to contact the main researcher Daniel de la Flor.

If you have any complaint, please contact Professor Hua Zhao, Chair of the Research Ethics Committee for the College of Engineering, Design and Physical Sciences.

All data will be collected and stored in accordance with the Data Protection Act 1998.
This activity has been approved by the Research Ethics Committee as of 5th April 2018.

Researcher details: Daniel de la Flor Aceituno *Daniel.DeLaFlorAceituno@brunel.ac.uk*

Study 3 for participants collaborating as 'Interviewees'.

Information Sheet for Research Participants

You will be given a copy of this information sheet.

A driving simulator study to inform the design of an Automotive Habitat Lab.

We would like to invite you to participate in this research project. It involves the evaluation of creativity in a set of interviews conducted while people were using a driving simulator. Estimated duration: 50 minutes.

What is the study about?

This study involves collaboration with two types of participants: interviewees and experts. The interviewees will be asked a set of questions regarding navigation systems in cars and requested to provide ideas to improve them. Half of the interviews will take place in a driving simulator while participants are driving and the other half will take place in an isolated room, in order to study the influence of the driving task on the answers. After collecting the information from interviewees, the conversations will be transcribed and sent to the experts for further analysis.

What do the researchers want to find out?

We want to find out if car drivers report more creative ideas while driving than when asked in an empty room.

Do I have to take part? No. It is completely up to you whether you take part or not.

What happens to my information?

Information acquired during the course of the user trials will be used solely for the purposes of the research. Personal data from participants will be limited to the consent form, with an ID number allocated to each participant which will then be associated with the study data. No names or personally identifying information will be used outside those directly involved in the collection, transcription and analysis of these data, and the supervision of this; no personally identifying information will appear in internal or external reports and publications. Hard copy consent forms, simulator sickness questionnaire and study sensitive data (such as participants' contact details) will be kept in a locked filing cabinet and will be destroyed once the study has taken place or – if it cannot be scheduled – at the end of the data collection phase. All electronic files which can or may contain information related to this experiment will be stored only on the Brunel and/or departmental computer systems, therefore, protected with a password. Personally identifying data will be removed and transcriptions anonymised at the earliest available opportunity (e.g. by replacing any names mentioned with pseudonyms). Once transcribed and once the transcription is checked, electronic files will be destroyed. The transcription will therefore not contain any personally identifying information. The lead researcher supervising the various studies within this project has completed the online Health and Safety Research Integrity course.

Why do I have to fill in a health form?
We will ask you to fill in a health form- the purpose of this is only for us to decide whether you are eligible to participate as a driver in this study. For reasons of health and safety, if you suffer from any of the conditions that are included in the form, we would exclude you from this study.

Can I find out the results of the study?
Yes. If you would like to be sent a copy of the study report or you have any question/suggestion, please contact the researcher using the email or phone number above.

Can I keep this information sheet?
Yes, this information sheet is for you to keep.

If you have any query, please do not hesitate to contact the main researcher Daniel de la Flor.

If you have any complaint, please contact Professor Hua Zhao, Chair of the Research Ethics Committee for the College of Engineering, Design and Physical Sciences.

All data will be collected and stored in accordance with the Data Protection Act 1998.
This activity has been approved by the Research Ethics Committee as of 5th April 2018.

Researcher details: Daniel de la Flor Aceituno *Daniel.DeLaFlorAceituno@brunel.ac.uk*

Study 4 for participants collaborating as 'Interviewees'.

Information Sheet for Research Participants

You will be given a copy of this information sheet.

A driving study to inform the design of an Automotive Habitat Lab.

We would like to invite you to participate in this research project. It involves the evaluation of creativity in a set of interviews conducted while people are driving. Estimated duration: 20-30 minutes.

What is the study about?

This study involves collaboration with two types of participants: interviewees and experts. The interviewees will be asked a set of questions regarding navigation systems in cars and requested to provide ideas to improve them. The interviews will take place while interviewees are driving and will be supported by the hands-free equipment of a Land Rover Discovery Sport (telephone call). The goal of the experiment is to study the influence of the driving task on the creativity of the answers. After collecting the information from interviewees, the conversations will be transcribed and sent to the experts for further analysis.

What do the researchers want to find out?

We want to find out if car drivers report more creative ideas while driving than when asked in an empty room.

Do I have to take part? No. It is completely up to you whether you take part or not.

What happens to my information?

Information acquired during the course of the user trials will be used solely for the purposes of the research. Personal data from participants will be limited to the consent form, with an ID number allocated to each participant which will then be associated with the study data. No names or personally identifying information will be used outside those directly involved in the collection, transcription and analysis of these data, and the supervision of this; no personally identifying information will appear in internal or external reports and publications. Hard copy consent forms, simulator sickness questionnaire and study sensitive data (such as participants' contact details) will be kept in a locked filing cabinet and will be destroyed once the study has taken place or – if it cannot be scheduled – at the end of the data collection phase. All electronic files which can or may contain information related to this experiment will be stored only on the Brunel and/or departmental computer systems, therefore, protected with a password. Personally identifying data will be removed and transcriptions anonymised at the earliest available opportunity (e.g. by replacing any names mentioned with pseudonyms). Once transcribed and once the transcription is checked, electronic files will be destroyed. The transcription will therefore not contain any personally identifying information. The lead researcher supervising the various studies within this project has completed the online Health and Safety Research Integrity course.

Why do I have to fill in some screening questions?
We will ask you to fill in a health form- the purpose of this is only for us to decide whether you are eligible to participate as a driver in this study. For reasons of health and safety, if you do not pass the risk assessment for driving ability we would exclude you from this study.

Can I find out the results of the study?
Yes. If you would like to be sent a copy of the study report or you have any question/suggestion, please contact the researcher using the email or phone number above.

Can I keep this information sheet?
Yes, this information sheet is for you to keep.

If you have any query, please do not hesitate to contact the main researcher Daniel de la Flor.

If you have any complaint, please contact Professor Hua Zhao, Chair of the Research Ethics Committee for the College of Engineering, Design and Physical Sciences.

All data will be collected and stored in accordance with the Data Protection Act 1998.
This activity has been approved by the Research Ethics Committee as of 14th November 2018.

Researcher details: Daniel de la Flor Aceituno *Daniel.DeLaFlorAceituno@brunel.ac.uk*

Appendix B: Health Form for Research Participants

Studies 1, 2 and 3 for participants who were assigned to use the driving simulator.

Health Form for Research Participants

Please complete this form after you have read the Information Sheet.

A driving simulator study to inform the design of an Automotive Habitat Lab.

This study has been approved by the Brunel University Research Ethics Committee.
Thank you for your interest in taking part in this research.

Participant's Statement

Please tick the appropriate box

Do you suffer from any of the following:

Migraines	YES □	NO □
Epilepsy	YES □	NO □
Motion Sickness	YES □	NO □
Vertigo	YES □	NO □
Postural Instability	YES □	NO □
Blurred Vision	YES □	NO □
Fatigue	YES □	NO □
Ear blockages	YES □	NO □
Upper respiratory illness	YES □	NO □

Have you recently (in the last 12 hours) taken medications or alcohol? YES □ NO □

Are you or could you be pregnant? YES □ NO □

Signed: ……………………………………….

Participant Name: ……………………………………… Date: ……………………………….

Appendix C: Simulator Sickness Questionnaire

Studies 1, 2 and 3 for participants who were assigned to use the driving simulator.

Simulator Sickness Questionnaire

Instructions: Circle how much each symptom below is affecting you right now.

1.	General discomfort	None	Slight	Moderate	Severe
2.	Fatigue	None	Slight	Moderate	Severe
3.	Headache	None	Slight	Moderate	Severe
4.	Eye strain	None	Slight	Moderate	Severe
5.	Difficulty focusing	None	Slight	Moderate	Severe
6.	Salivation increasing	None	Slight	Moderate	Severe
7.	Sweating	None	Slight	Moderate	Severe
8.	Nausea	None	Slight	Moderate	Severe
9.	Difficulty concentrating	None	Slight	Moderate	Severe
10.	<Fullness of the Head>	None	Slight	Moderate	Severe
11.	Blurred Vision	None	Slight	Moderate	Severe
12.	Dizziness with eyes open	None	Slight	Moderate	Severe
13.	Dizziness with eyes closed	None	Slight	Moderate	Severe
14.	*Vertigo	None	Slight	Moderate	Severe
15.	**Stomach awareness	None	Slight	Moderate	Severe
16.	Burping	None	Slight	Moderate	Severe

*Vertigo is experienced as a loss of orientation with respect to vertical upright.
** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

Appendix D: Consent forms and Screening Questions

Studies 1, 2, 3 and 4.

Consent Form for Research Participants

Please complete this form after you have read the Information Sheet.

A driving simulator study to inform the design of an Automotive Habitat Lab.

This study has been approved by the Brunel University Research Ethics Committee.
Thank you for your interest in taking part in this research. Before you agree with taking part, the person organising the research must explain the project to you. If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join it.

Participant's Statement	*Please tick the appropriate box*
• Have you read the Research Participant Information	YES □ NO □
• Do you understand that you will not be referred to by name in any report concerning the study?	YES □ NO □
• Do you understand that you are free to withdraw from the study before the results are published without having to give a reason for withdrawing?	YES □ NO □
• I agree with the use of non-attributable quotes when the study is written up or published.	YES □ NO □
• I agree that the research project named above has been explained to my satisfaction and I agree with taking part in this study.	YES □ NO □
• I understand that the information I have submitted will be published as a report and that I can contact the researchers to get a copy.	YES □ NO □

Signed: ……………………………………….

Participant Name: ……………………………………… Date: ……………………………

This activity has been approved by the Research Ethics Committee as of (Day) (Month) (Year).

Study 4.

Testing a set of questions for an automotive co-design framework utility in real driving conditions

Screening Questions and Set-Up

Thank you for taking part in this research. Before you agree with taking part, please answer the following screening questions. If you have any question arising from any of the Information sheet, the consent form or this document please ask the researcher before deciding whether to join in.

□ Are you an experienced, confident driver?

□ Are you a Brunel student or staff member?

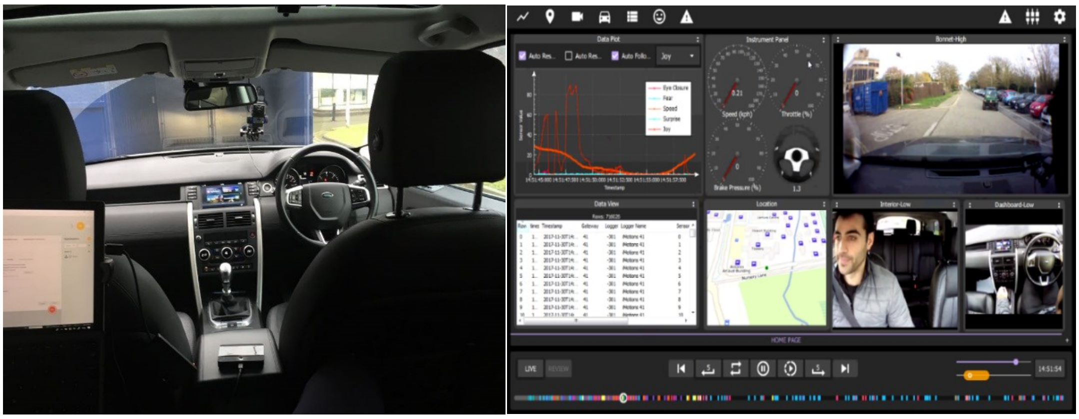
□ Do you have a full and clean driver's license?

If you decide to take part in the study, please send in advance copies/photographs of your license and Brunel card/proof of identity.

Set-Up and Route:

The car used for the study is a Land Rover Discovery Sport equipped with 3 cameras. One pointing the driver's face and connected to a facial recognition software to track your mood during the study, a second camera pointing the dashboard to subjectively supervise your body language and the last camera pointing the windshield to ensure the traffic conditions you will face are recorded.

You could drive freely without having to follow any specific route and eventually, you receive a telephone call on the hands-free of the car. Once you answer the call we could start with the interview.



This activity has been approved by the Research Ethics Committee as of 14th November 2018.

Appendix E: Ethics Approvals

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

12 July 2016

LETTER OF APPROVAL

Applicant: Mr Daniel de la Flor Aceituno

Project Title: Automotive Habitat Lab Exp1

Reference: 3103-MHR-Jul/2016- 3405-2

Dear Mr Daniel de la Flor Aceituno

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.
- No research data collected prior to this ethical approval should be included in your research.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

9 February 2017

LETTER OF CONDITIONAL APPROVAL

Applicant: Mr Daniel de la Flor Aceituno

Project Title: Co-design and Telepresence

Reference: 4485-MHR-Feb/2017- 5889-1

Dear Mr Daniel de la Flor Aceituno

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**
- **Please check the period that you need to keep the data and signed consent forms with your supervisor and amend the Participant Information Sheet accordingly.**
- **Please ensure that you have a fellow student with you at all times while the research is taking place.**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

Page 1 of 1

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

5 April 2018

LETTER OF APPROVAL (CONDITIONAL)

Applicant: Mr Daniel de la Flor Aceituno

Project Title: Evaluating creativity: Driving simulator vs. Empty room

Reference: 10883-MHR-Mar/2018- 12323-1

Dear Mr Daniel de la Flor Aceituno

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.
- Start date has passed. Please be advised that no research activity involving human participants can commence without ethical approval in place.
- Please check with your supervisor regarding data retention policies.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

14 November 2018

LETTER OF APPROVAL

Applicant: Mr Daniel de la Flor Aceituno

Project Title: Evaluating creativity: Driving a real car

Reference: 13497-LR-Nov/2018- 14717-1

Dear Mr Daniel de la Flor Aceituno

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

Appendix F: Post-task Questionnaires

Appendix F.1: Questionnaire sheets for participants and researcher in study 1

Appendix F.1.1: Questionnaire sheet for participants

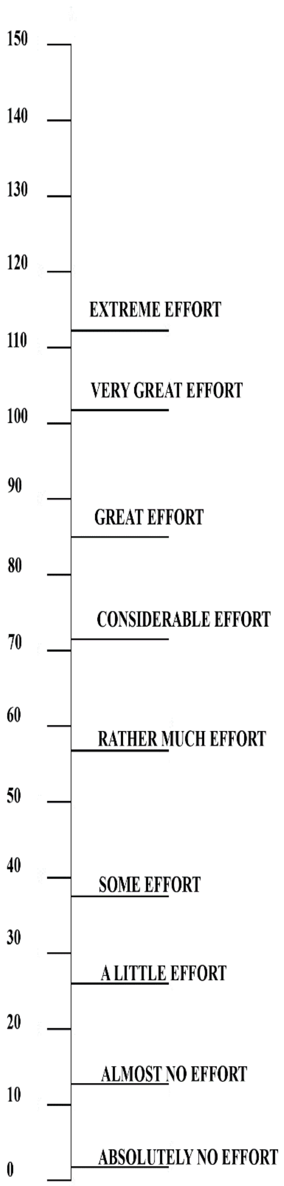
Name:	Task:	Round:

ITU-T P.910 and SMEQ Questionnaires

Could you kindly answer the following questions about the last sequence shown?

You can express your opinion by inserting a mark on the scales below.

In the scale shown on the left, please mark the mental effort that you needed to complete the task.



1) How would you rate image borders?

Bad Excellent

2) How would you rate image colours?

Bad Excellent

3) How would you rate image contrast?

Bad Excellent

4) How would you rate the movement continuity?

Bad Excellent

Appendix F.1.2: Questionnaire sheet for the researcher

Error Rate Evaluation

This form must be completed by the researcher.

Size: ………. Resolution: …….. Volume:……..	Task 1	Task 2	Task 3
1st Round Value: …………	Task name:	Task name:	Task name:
	Correct solution:	Correct solution:	Correct solution:
	Obtained result:	Obtained result:	Obtained result:
2nd Round Value: …………	Task name:	Task name:	Task name:
	Correct solution:	Correct solution:	Correct solution:
	Obtained result:	Obtained result:	Obtained result:
3rd Round Value: …………	Task name:	Task name:	Task name:
	Correct solution:	Correct solution:	Correct solution:
	Obtained result:	Obtained result:	Obtained result:

Participant Name: ……………………………………… Date: ………………………………

Appendix F.2: Questionnaire sheets for participants in study 2

Name: Role (driver/assistant):

After finishing the activities and delivered the results, please read carefully and answer these questions by filling the circle that better fit to your impressions when you were collaborating with your fellow. I.e. Not chosen response: ○ Chosen response: ●

Self-reported co-presence:

1-5 strongly agree, strongly disagree

- I did not want a deeper relationship with my interaction partner:

○ Strongly agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly disagree

- I wanted to maintain a sense of distance between us:

○ Strongly agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly disagree

- I wanted to make the conversation more intimate:

○ Strongly agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly disagree

- I tried to create a sense of closeness between us:

○ Strongly agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly disagree

- I was interested in talking to my interaction partner:

○ Strongly agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly disagree

Perceived other's co-presence:

1-5 strongly agree, strongly disagree

- My interaction partner was intensely involved in our interaction:

○ Strongly agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly disagree

- My interaction partner seemed to find our interaction stimulating:

○ Strongly agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly disagree

- My interaction partner made our conversation seem intimate:

○ Strongly agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly disagree

- My interaction partner created a sense of closeness between us:

○ Strongly agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly disagree

- My interaction partner showed enthusiasm while talking to me:

○ Strongly agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly disagree

Social presence:

Please put a cross on the horizontal axis where you consider convenient according to your experience. I.e. A I-------------------X---I B

Sliding scale

- To what extent did you feel able to assess your partner's reactions to what you said?

Able to assess reactions |--| Not able to assess reactions

- To what extent was this like a face-to-face meeting?

A lot like face to face |--| Not like face to face at all

- To what extent was this like you were in the same room with your partner? A lot like being in the same room, not like being in the same room at all.

A lot like being in the same room |--| Not like being in the same room

- How likely is it that you would choose to use this system of interaction for a meeting in which you wanted to persuade others of something? (face to face / voice call / video call)

Very likely |--| Not likely at all

- To what extent did you feel you could get to know someone that you met only through this system? - Very well, not at all.

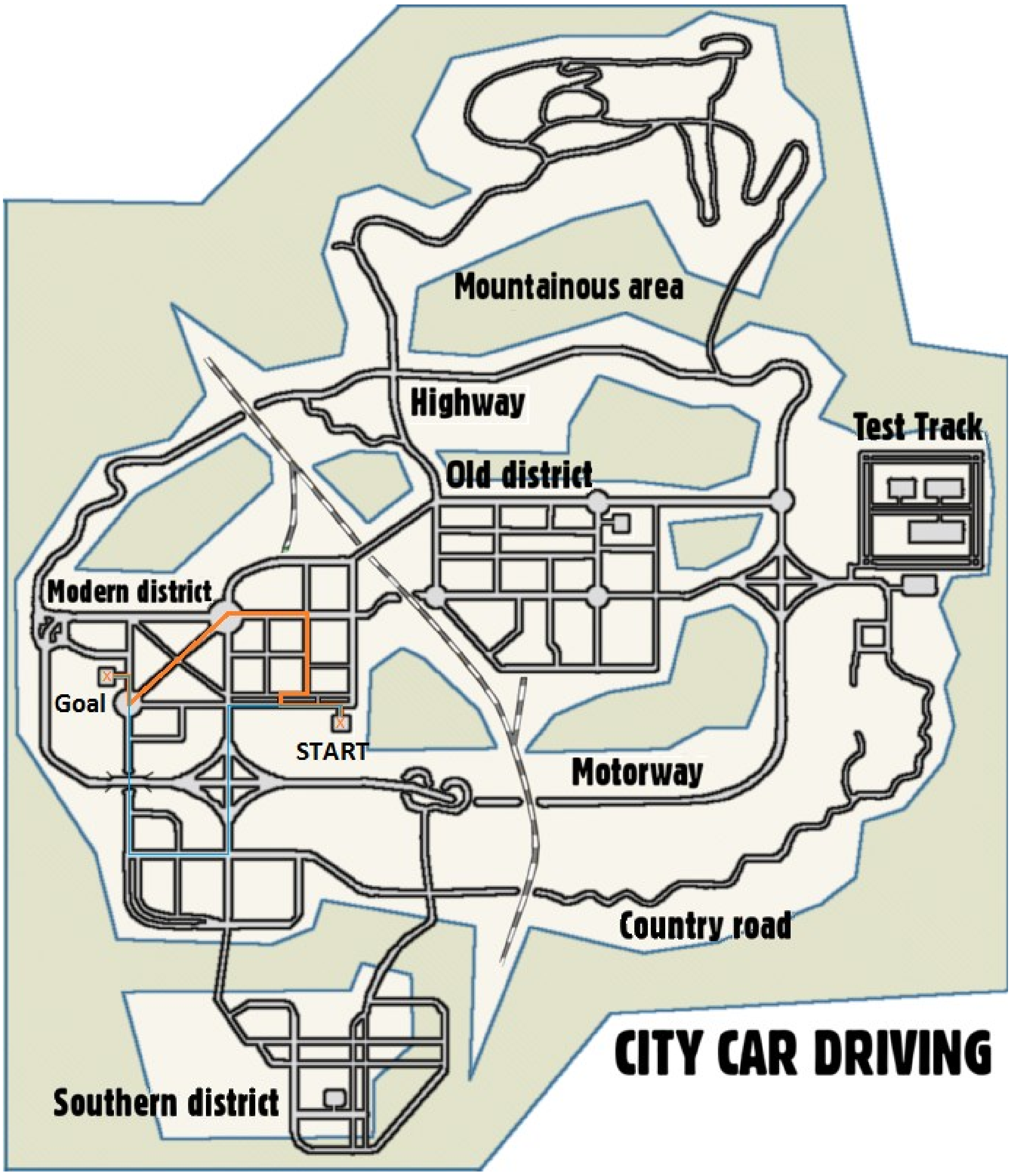
Very well |--| Not at all

Appendix F.2: Questionnaire sheets for participants (study 2)

Welcome to the control room. During these tests, you will interpret the role of the assistant and your duty will consist in guiding and helping the driver to reach the best possible results. To reach this goal, you will have to collaborate as a team and complete two different activities.

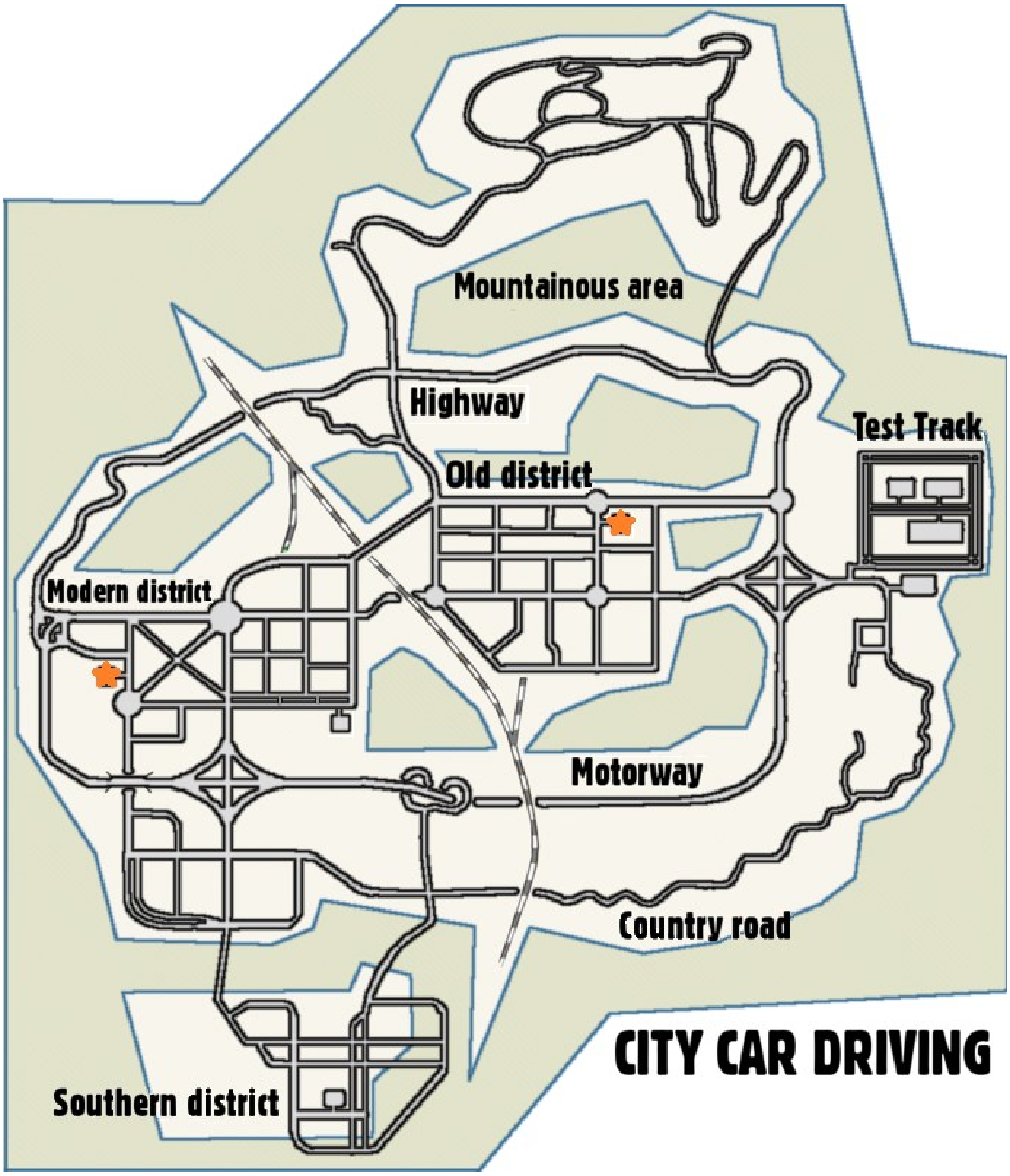
Activity 1: Collaborative Navigation (stage A)

The next map shows the city where the car is. The navigation will start and end at the Modern District. The driver has a copy of this map excluding the alternative routes he/she can take (it only contains the starting point and the goal). You will not have information about the car's location, so we would suggest you ask the driver for visual feedback in order to keep the vehicle tracked all the time.



Activity 1: Collaborative Navigation (stage B)

The next map shows the city where the car is. This task starts where stage A ended. This time the driver has no map and you will have to give him/her instructions to get to the goal. You will not have information about the car's location, so we would suggest you ask the driver for visual feedback in order to keep the vehicle tracked all the time.



Activity 2: Answering the riddle (10 minutes)

Could you please collaborate with your partner to solve these riddles while he/she is driving? The driver now can feel free to take any route and focus on the riddles. You can take any notes you need on the box below.

- What can travel around the world while staying in a corner?

Answer: _______________

- What has a head and a tail, but not a body?

Answer: _______________

- Feed me and I live, give me drink and I die. What am I?

Answer: _______________

Write your notes here:

Appendix F.3: Questionnaire sheets for expert participants in studies 3 and 4

Thank you for taking part in this experiment as a qualified expert. Your opinion means a lot for the purposes of this research and we would like to hear from you. In addition to this document, you will receive several transcripts with ideas about how to improve navigation systems. We would like you to sort these ideas from the least to the most creative ones and we prepared two activities to make it easier for you.

Activity 1: Creativity definition

First things first, you might need to reflect on what you will understand for a creative idea, so would you share with us what "Creativity" means for you? You can feel free to include examples, other definitions or diagrams/pictures that might help you to express yourself.

Write your answer here:

Activity 2: Criteria to assess Creativity

Now that you have defined creativity, it is important to explain how you would measure it. Which elements would you pay attention to evaluate how creative is an idea? This time too, you can feel free to include examples, other definitions or diagrams/pictures that might help you to be clear.

Write your answer here:

Activity 3: Ranking the ideas

Now you are ready to rank the ideas we gave you. What is the most creative idea you found? Why? What is the least creative idea? Why? Please, include in the list ALL the ideas we sent to you. The exact order in which they are listed will affect the outcomes of the research.

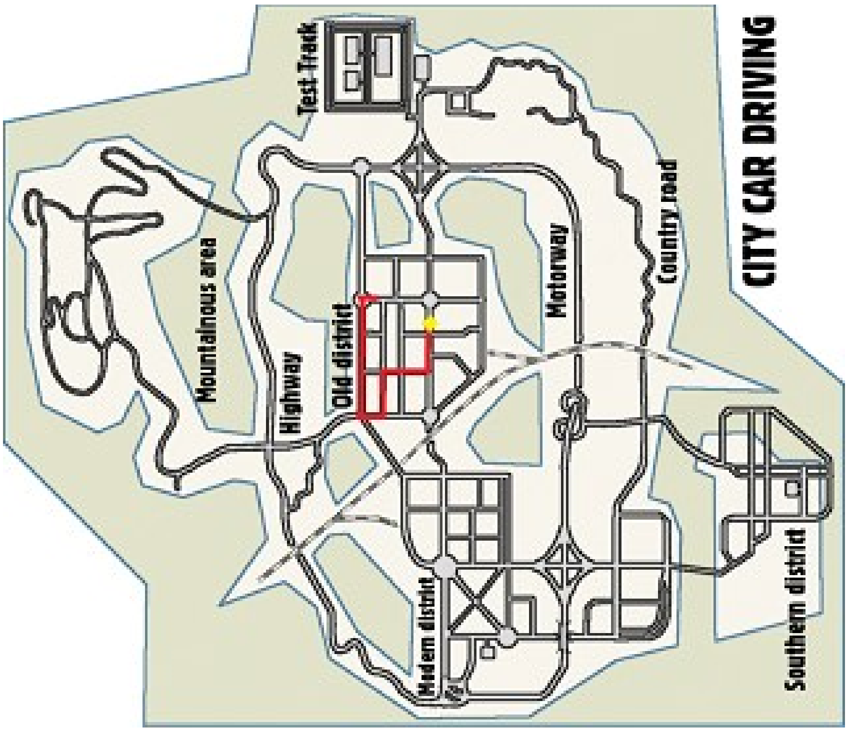
Ranking (1-Most creative; 28-Least creative):

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.
21.
22.
23.
24.
25.
26.
27.
28.

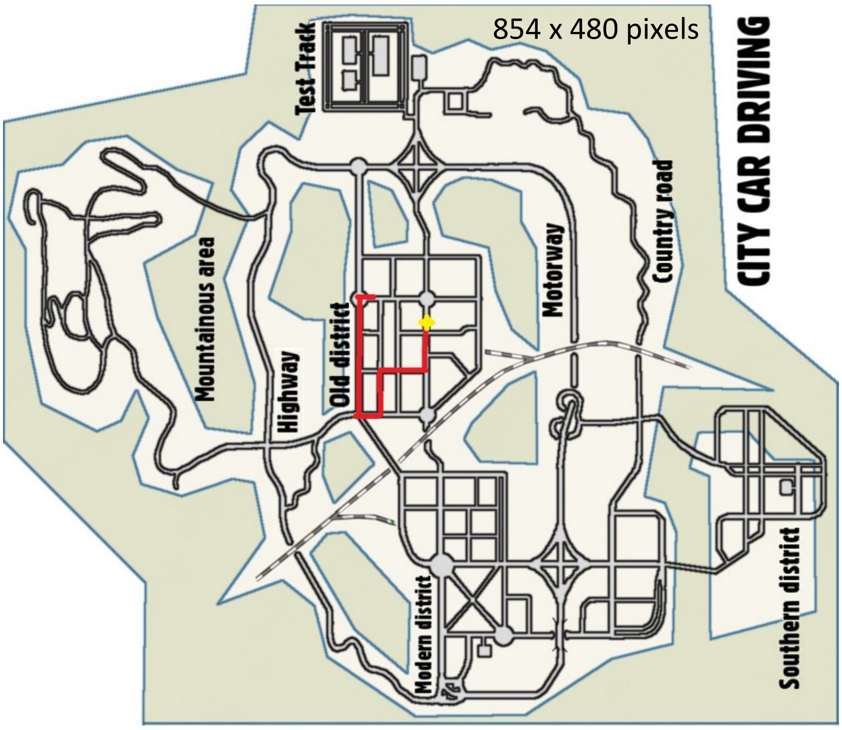
Appendix G: Stimulus materials and additional analyses

Appendix G.1: Stimulus materials for study 1

A sample of the pictures used for Image task in both proposed resolutions:



854 x 480 pixels



320 x 180 p

The transcription of the speeches used for the audio tasks:

Audio 1: The Alchemist Plot (2020). *The Alchemist (novel)*. Available at: https://en.wikipedia.org/wiki/The_Alchemist_(novel). Accessed: 06 August 2020
Participants had to count the number of times that was pronounced the word: *Legend (8 times)*

The Alchemist follows the journey of a Spanish shepherd boy named Santiago. Believing a recurring dream to be prophetic, Santiago decides to travel to a Roman fortune-teller in a nearby town to discover its meaning. The woman interprets the dream as a prophecy telling the boy that there is a treasure in the pyramids in Egypt. Early into his journey, he meets an old king, whose name was Melchizedek, who tells him to sell his sheep to travel to Egypt and introduces the idea of a Personal Legend. Your Personal Legend "is what you have always wanted to accomplish. Everyone, when they are young, knows what their Personal Legend is. He adds that "when you want something, all the universe conspires in helping you to achieve it." This is the core theme of the book. Along the way, Santiago meets an Englishman who has come in search of an Alchemist and continues his travels with him. They travel through the Sahara desert and during his journey, Santiago meets and falls in love with a beautiful Arabian woman named Fatima, who resides with her clan near around the desert Oasis. He asks Fatima to marry him, but she says she will only marry him after he completes his journey and finds his treasures. He is perplexed by this but later learns that true love will not stop nor plead to sacrifice one's Personal Legend, and if it does, it is not true love. Santiago then encounters a lone alchemist who also teaches him about Personal Legends. He says that people want to find only the treasure of their Personal Legends but not the Personal Legend itself. Santiago feels unsure about himself as he listens to the alchemist's teachings. The alchemist states, "Those who don't understand their Personal Legends will fail to comprehend their teachings." It is also stated that treasure is more worthy than gold. The main theme of the story is defined by this quote, which recurs all through the novel, "When a person really desires something, all the universe conspires to help that person to realise his dream." It denotes the power of desires and passion and its ability to manifest it in real life.

Audio 2: Harry Potter Plot (2020). *Harry Potter*. Available at: https://en.wikipedia.org/wiki/Harry_Potter. Accessed: 06 August 2020
Participants had to count the number of times that was pronounced the word: *Harry (6 times)*

The central character in the series is Harry Potter, an English orphan who discovers, at the age of eleven, that he is a wizard, though he lives in the ordinary world of non-magical people known as Muggles. The magician world exists parallel to the Muggle world, albeit hidden and in secrecy. His magical ability is inborn, and children with such abilities are invited to attend exclusive magic schools that teach the necessary skills to succeed in the magician world. Harry becomes a student at Hogwarts School of Witchcraft and Wizardry, a magician academy in Scotland, and it is here where most of the events in the series take place. As Harry develops through his adolescence, he learns to overcome the problems that face him: magical, social and emotional, including ordinary teenage challenges such as friendships, infatuation, romantic relationships, schoolwork and exams, anxiety, depression, stress, and the greater test of preparing himself for the confrontation in the real world that lies ahead, in magician Britain's increasingly-violent second magician war. The magician world of Harry Potter exists in parallel within the real world and contains magical versions of the ordinary elements of everyday life, with the action mostly set in Scotland (Hogwarts), the West Country, Devon, London and Surrey in southeast England. The world only accessible to wizards and magical beings comprises a fragmented collection of overlooked hidden streets, ancient pubs, lonely country manors and secluded castles invisible to the Muggle population. The environment Rowling created is intimately connected to reality. The British magical community of the Harry Potter books is inspired by 1990s British culture, European folklore, classical mythology and alchemy, incorporating objects and wildlife such as magic wands, magic plants, potions, and spells, flying broomsticks, centaurs and other magical creatures, the Deathly Hallows, and the Philosopher's Stone, beside others invented by Rowling. The wizarding world of Harry Potter exists in parallel within the real world and contains magical versions of the ordinary elements of everyday life, with the action mostly set in Scotland (Hogwarts), the West Country, Devon, London and Surrey in southeast England. The world only accessible to wizards and magical beings comprises a fragmented collection of overlooked hidden streets, ancient pubs, lonely country manors and secluded castles invisible to the Muggle population.

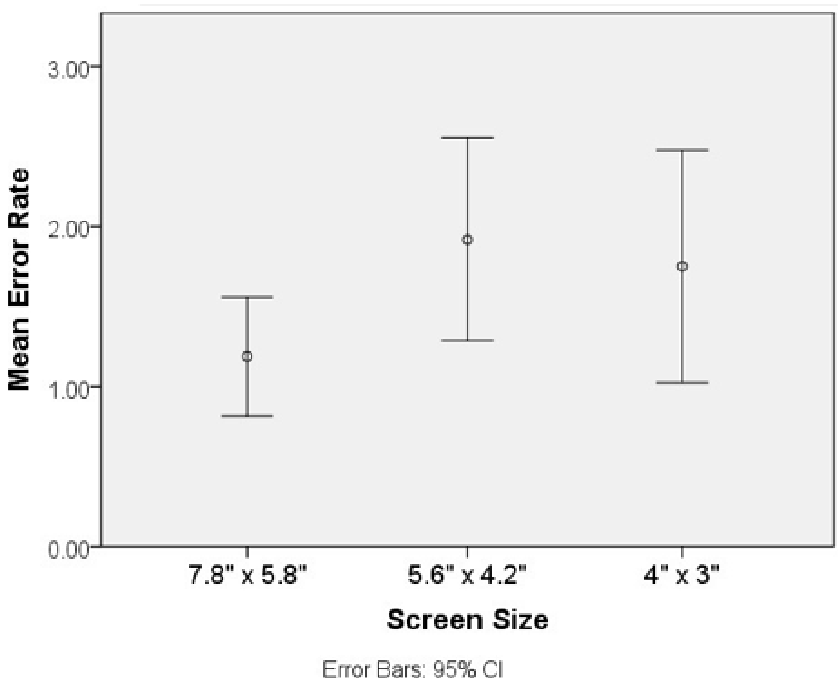
Audio 3: A Perfect Person (2020). *Short Stories*. Available at:
http://shortstoriesshort.com/story/a-perfect-person/. Accessed: 06 August 2020
Participants had to count the number of times that was pronounced the word: *Husband (6 times)*

A man and his girlfriend were married. It was a large celebration. All of their friends and family came to see the lovely ceremony. The bride was gorgeous in her white wedding gown and the groom was very dashing in his black suit. Everyone could tell that the love they had for each other was true. A few months later, the wife comes to the husband with a proposal: "I read in a magazine a while ago, about how we can strengthen our marriage." she offered. "Each of us will write a list of the things that we find a bit annoying with the other person. Then, we can talk about how we can fix them together and make our lives happier together." The husband agreed, so each of them went to a separate room in the house and thought of the things that annoyed them about the other. They thought about this question for the rest of the day and wrote down what they came up with. The next morning, at the breakfast table, they decided that they would go over their lists. "I'll start," offered the wife. She took out her list. It had many items on it enough to fill 3 pages, in fact. As she started reading the list of the little annoyances, she noticed that tears were starting to appear in her husband's eyes. "What's wrong?" she asked. "Nothing" the husband replied, "keep reading your lists." The wife continued to read until she had read all three pages to her husband. She neatly placed her list on the table and folded her hands over the top of it. "Now, you read your list and then we'll talk about the things on both of our lists." She said happily. Quietly the husband stated, "I don't have anything on my list. I think that you are perfect the way that you are. I don't want you to change anything for me. You are lovely and wonderful and I wouldn't want to try and change anything about you." The wife, touched by his honesty and the depth of his love for her and his acceptance of her, turned her head and wept.

Appendix G.2: Additional analyses for the error rate of participants in study 1

The effect of the screen size on the error rate

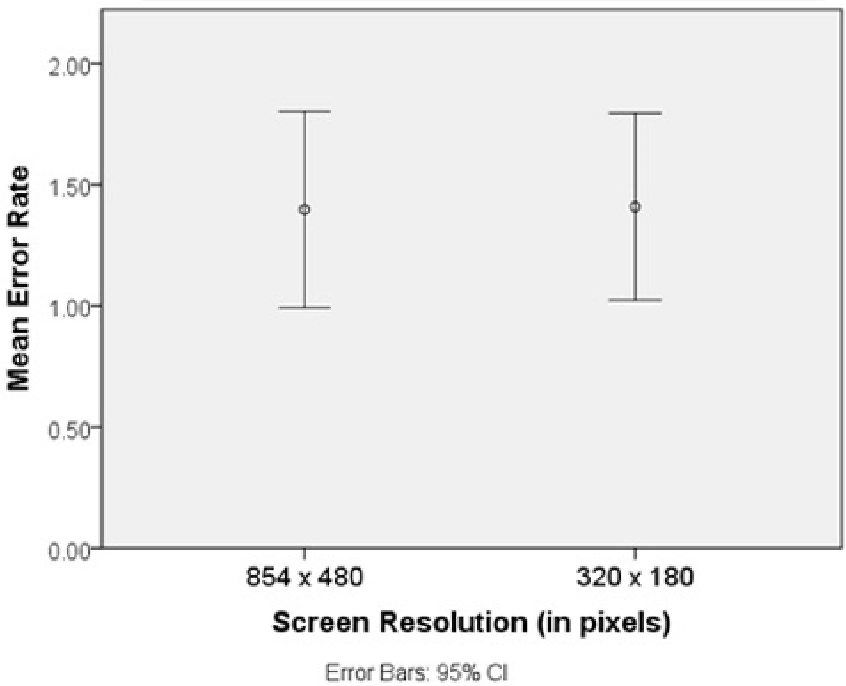
There is not a statistically significant difference on the error rates when using different screen sizes (F = 3.774, p-value = 0.025 based on the test of homogeneity of variances and F = 1.864, p-value = 0.169 from the robust test of equality of means). This analysis is based on the data collected from participants performing image and video tasks.



	Error rate	
Screen Size	**Mean**	**SD**
7.8" x 5.8"	1.187	1.453
5.6" x 4.2"	1.917	1.847
4" x 3"	1.750	2.044

The effect of the screen resolution on the error rate

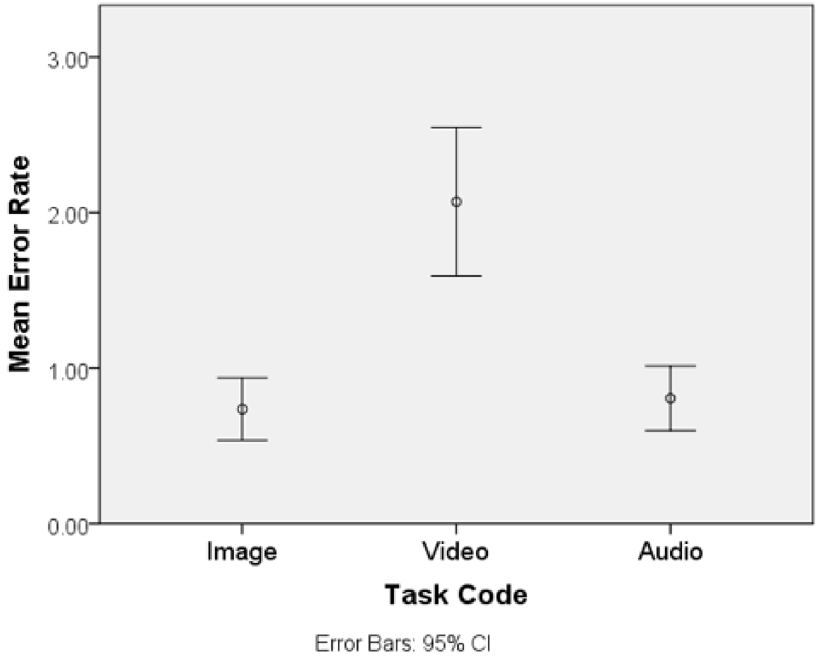
There is not a statistically significant difference on the error rates when using different screen resolutions (F = 0.486, p-value = 0.487 based on the test of homogeneity of variances and F = 0.002, p-value = 0.967 on the One-Way ANOVA test). This analysis is based on the data collected from participants performing image and video tasks.



	Error rate	
Screen Size	**Mean**	**SD**
854 x 480	1.409	1.569
320 x 180	1.397	1.797

The effect of the secondary task on the error rate

There is a statistically significant difference on the error rates when participants performed the different secondary tasks (F = 30.522, p-value = 0.000 based on the test of homogeneity of variances and F = 13.562, p-value = 0.000 from the robust test of equality of means). This analysis is based on the data collected from all the participants. A Post Hoc Analysis can be conducted to determine the tasks that present different means and a Tukey HSD reported the video task to provide different results to the other two tasks, with a mean difference of 1.333, standard error of 0.228 (p = 0.000) between the video task and the image task, and a mean difference of 1.264, a standard error of 0.228 (p = 0.000) between the video task and the audio task.



	Error rate	
Secondary task	Mean	SD
Image	0.736	0.856
Video	2.069	2.030
Audio	0.806	0.882

Note that as mentioned in section 4.5 the criteria used to measure the error rate for the three different task types is different, which makes the results not strictly comparable. However, the significant differences found in regards to the effect of the video task on the error rate and the perceived mental effort by the participants suggest the need for prolonged attention to the on-board screen to offer a dangerously challenging distraction to users while driving and multitasking.

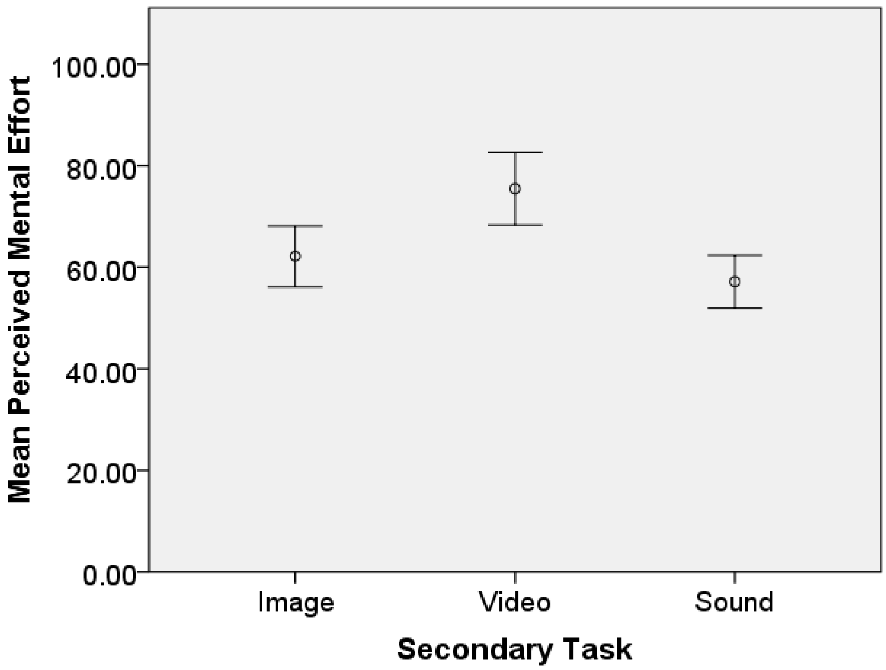
The relationship between the secondary task and the perceived mental effort

While the study 1 was conducted, the main researcher noticed participants to repeatedly report the video task as more demanding in terms of mental effort than the image task audio task. Previous literature (Lerner et al., 2015; Singer et al., 2015) suggests that recognition times depend on the number of stimuli pointing to the user. In this case, the video task requires the user to integrate mentally a sequence of frames as a clip, involving the management of a larger amount of information than the image or the audio task. Therefore, in order to confirm if the video task was perceived as significantly more demanding than the other task in terms of mental effort, a One-Way ANOVA was performed. This analysis included all the data collected (n = 24), and it revealed with F = 9.344 and a p-value of 0.000 that there is a significant difference between the variances of the samples taken of the three tasks. The next table confirms such hypothesis with the significances lower than 0.05 (Post Hoc Test: Tukey HSD) and the figure presented subsequently confirms graphically the same difference.

Dependent Variable: Perceived Mental Effort
Tukey HSD

(I) Task Code	(J) Task Code	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Image	Video	-13.30556*	4.38008	.008	-23.6435	-2.9676
	Sound	5.01389	4.38008	.488	-5.3240	15.3518
Video	Image	13.30556*	4.38008	.008	2.9676	23.6435
	Sound	18.31944*	4.38008	.000	7.9815	28.6574
Sound	Image	-5.01389	4.38008	.488	-15.3518	5.3240
	Video	-18.31944*	4.38008	.000	-28.6574	-7.9815

*. The mean difference is significant at the 0.05 level.



Error Bars: 95% CI

Appendix G.3: Script used by the researcher as the guideline for the interview

STAGE 1: OPENING

Good afternoon XXXX, how are you? As a quick reminder I am running some interviews to basically achieve three goals:

- Collect feedback about navigation systems
- Assess if they meet properly user expectations if you are happy with them.
- Gather creative ideas to improve these tools in case you had any suggestion

In case you were not familiar with the navigation system of your car you can also think about Google Maps or any other tool you are familiar with. Does it sound ok to you?

STAGE 2: ENABLING ACTION

Every story has a beginning so I would like to know how yours started... So how many years have you been driving so far?

How old were you when you got the driving license?

What was your motivation for getting the driving license?

Currently, do you usually drive? Around how many days a week could we say?

And how often do you use the navigation system? (Clarify if we speak about Google Maps, the SAT NAV of the car or any other tool)

STAGE 3: ADDRESSING THE MAIN EVENT

How would you describe the overall process of setting up or using a navigation tool? Is it easy…? Is it intuitive…? Is it hard…?

Have you ever gotten lost even though you were using the navigation system of your car? (If so) what happened? What happened next?

Do you think there is any way these tools could be improved?

Now let's think out of the box, apart from guiding us to the place we want to go, could you find an alternative use for the navigation system? (Give examples if needed)

And imagine one day you didn't have any plan for your evening, what would you think if the navigation tool could give you some suggestions? Why? Would you use that feature?

STAGE 4: CLOSING THE INTERVIEW

Let's get back to you, if you were to write a newspaper headline to summarise your experience with navigation systems what would it be? You can also think about the title of a movie

Which emotion would you use to describe your overall experience with navigation systems?

Well, that is everything we needed to know, it has been really nice to get to know you better XXXX! I hope we can speak again someday, thank you very much and have a nice day!

Appendix H: Diptych with guidelines for on-road contextual inquiry

Recommendations for the development of new questions:

The new questions are advised to address one discussion context, one discussion target and one discussion rhetoric (see table below). Questions to be included in sections 3 and 4 of the interview are also recommended to address also one discussion objective. To incorporate new questions to the interview, please follow these steps:

1. Select the part of the interview where the question will be incorporated.
2. Select the question type according to the recommendations for such stage of the interview.
3. Select the contents of the question according to the previous table.
4. Word and write the question.

	Discussion Context			Discussion Target			Discussion Rhetoric				Discussion Objective	
	Road and traffic conditions	Interaction with the vehicle or with other agents	Unexpected events, errors or emergencies	Component	System	Complete vehicle	Where	When	Why	How	Incremental innovation	Disruptive innovation
Q1												
Q2												
Q3												
Q4												
Q5												
...												
Qn												

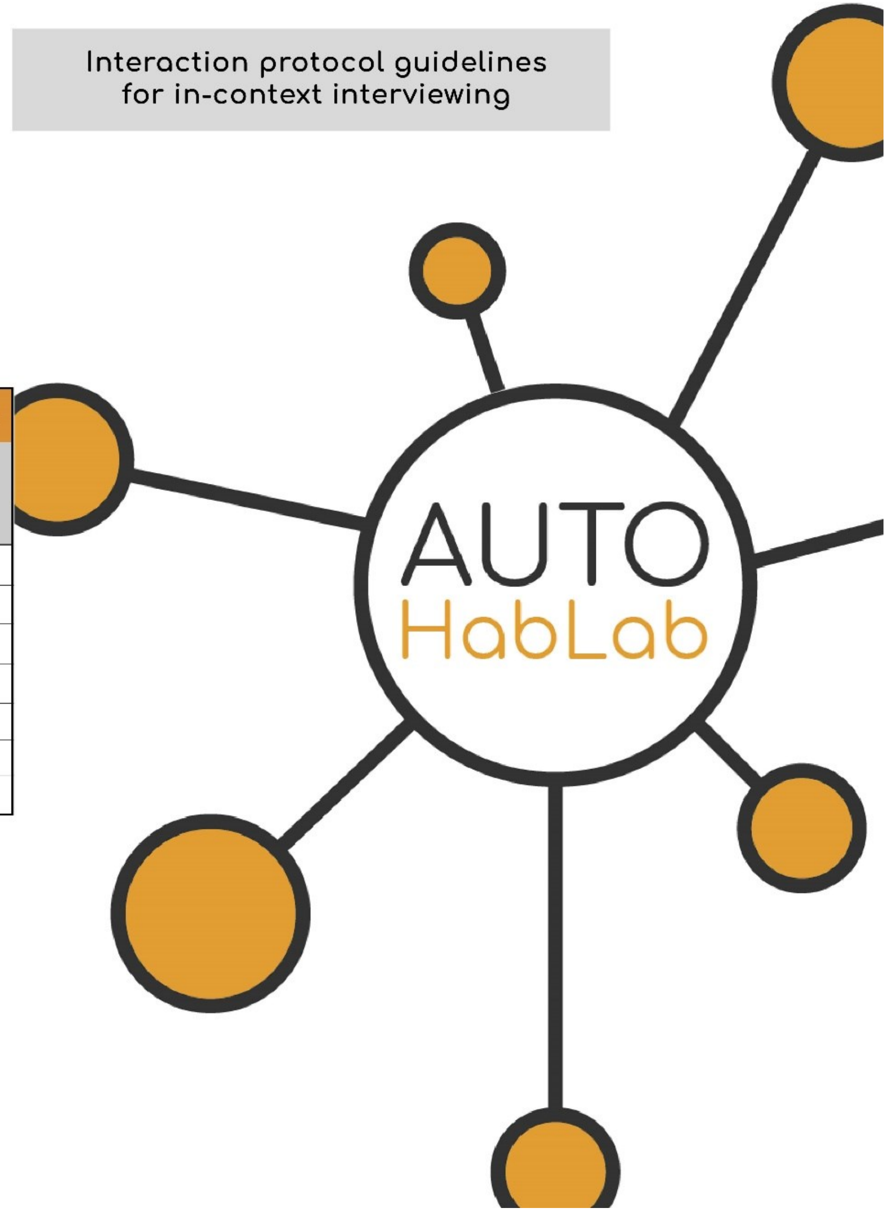
HCDI Human Centred Design Institute

Brunel University London

JAGUAR

LAND ROVER

Interaction protocol guidelines
for in-context interviewing



INTERACTION PROTOCOL STRUCTURE

Recommended structure for in-context interviews with automobile users:

Stage		
1. Opening the session	***Objective***	Getting to know each other, clarifying expectations, building commitment
	Questions recommended	Closed questions, experience questions
	Example	How are you? How many years have you been driving so far? Do you own a car?
2. Enabling action	***Objective***	Defining the topic
	Questions recommended	Experience questions, descriptive questions
	Example	How often do you drive a car? How often do you use the SAT NAV of your car? How do you find using it?
3. Thinking critically	***Objective***	Making assumptions explicit and exploring alternatives
	Questions recommended	Narrow questions, co-creation questions
	Example	What navigation tool do you prefer to use while driving? How would you describe the process of setting it up? Do you prefer listening to the voice instructions or looking at the mini-map?
4. Addressing issues	***Objective***	Understanding the situation, testing options, making decisions
	Questions recommended	Co-creation questions, open questions
	Example	Have you ever got lost even though you were using a navigation tool? Can you think of any way these tools could be improved? Can you think of any alternative use we could give to the navigation tool of the car?
5. Closing the session	***Objective***	Looking backward to wrap up the problem, considering future steps
	Questions recommended	Open questions, experience questions
	Example	How would you summarise your experience with navigation tools in a single sentence? If you were to summarise your experience with navigation tools with a feeling or emotion, what would it be? Why?

INTERACTION PROTOCOL QUESTIONS

Recommended question types for in-context interviews with automobile users:

1 Co-creation questions: used to encourage divergent thinking and generate creative ideas.
Example: What would you change in the navigation tool you typically use?

2 Open questions: used to collect a wide range of answers for a defined topic.
Example: How would you describe your overall experience using navigation tools?

3 Narrow questions: used to collect information regarding a specific unit of experience.
Example: How many years have you been driving so far?

4 Experience questions: used to collect feedback based on user experience.
Example: Do you prefer to follow the verbal, or visual instructions of the navigation tool?

5 Descriptive questions: used to keep respondents engaged to the conversation.
Example: What are the steps you typically follow to set up the navigation system?

Proposed uses for the co-creation questions:

- Reflecting about the general use of the device.
  Example: How would you describe the overall process of using a navigation tool?
- Guessing causes and consequences of a product failure.
  Example: Have you ever got lost even though you were using a navigation tool? What happened?
- Discussing possible product improvements.
  Example: Do you think there is any way in which these tools could be improved?
- Finding unusual uses for the device.
  Example: Apart from guiding us to the place we want to go, could you find any alternative use for the navigation system of your car?
- Guessing outcomes of an improbable situation.
  Example: What would you think if the navigation system could suggest you where to go beforehand?