FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Exploring Augmented Reality for the Automotive Retail Industry

Mariana Duarte Guimarães

Mestrado Integrado em Engenharia Informática

Supervisor: Maria Teresa Galvão Dias

September 21st, 2020

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Abstract

Car dealerships are operating in a fast-changing environment: the automotive retail industry is being disrupted by the shift in the mobility paradigm while facing a reduction in their margins due to third-party channels that provide increased transparency in vehicle pricing and reduce the ability to influence the consumers' buying behaviour. Also, with vehicles becoming more and more advanced, the complexity of information is also increasing, making the communication with clients more difficult. Considering this, automotive dealerships strive to be more consumer-centered, to create interactive experiences and to unveil new ways of brand management. The current dealership experience and contact should be improved upon, it should take into consideration the expectations and values of the newer generations and become more transparent, connected and convenient.

We propose to study the viability of AR technology as an effective tool in the automotive retail industry as a way to improve the current contact with clients. By examining the possibility of presenting the vehicle information in a more involving and comprehensive manner through the use of this technology and analyse the consumers perception of it. To do so, we will conduct research on current competitors' sales processes with integrated AR, as well as design and evaluate prototypes of visualization experiences as evidence to support our hypothesis.

Augmented Reality is chosen because it blends the components of a digital world into the individual's perception of reality [18], allowing for engaging and lifelike experiences. It also generates new ways to display and interact with information while connecting with the surroundings. By taking advantage of the potential to alter the feeling of presence through interactiveness, we expect to give valuable, helpful and consistent experiences to attract and retain more customers.

Keywords:Augmented Reality, Automotive Retail Industry, Consumer Behaviour, Marketing, Omni-channel Strategy, Service Science, User-Centered Design

Acknowledgments

I want to show my appreciation for everyone that helped me throughout these last few years, in particular during this thesis.

I want to express my gratitude to Losch Digital Lab for accepting this challenge. I will always cherish the entire team for all the support during the last year and for providing a great environment in which I always felt understood and encouraged.

To my family and friends, that always reassured me during the stressful times in this academic journey. Your kindness, love and support kept me going and none of this would have been possible without your help.

And lastly, to Prof. Maria Teresa Galvão Dias for the patience, enthusiasm and confidence in me during the development of this research.

Thank you all.

Mariana Duarte Guimarães

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Abbreviations

AR	Augmented Reality
MR	Mixed Reality
AV	Augmented Virtuality
VR	Virtual Reality
HMD	Head-Mounted Display
OEMs	Original Equipment Manufacturers
HCI	Human-Computer Interaction
WoW	"window-on-the-world"
SSME	Service Science Management and Engineering

Chapter 1

Introduction

This dissertation aims to analyse Augmented Reality as an effective tool to bring competitive advantage in the automotive retail industry through the creation of valuable and engaging experiences for costumers. In order to do this, it is important to study Augmented Reality and its effects on users, as well as consumers' expectations in this industry. In this chapter is laid out an overview of the current research, along with the scope, conditions and assumptions of the dissertation.

1.1 Problem Context

The automotive retail industry is being disrupted by four big trends: the rise of autonomous cars, electrification, connectivity and shared mobility, forcing change in the traditional distribution and market dynamics. This demands an improvement of the sales process, making it more consumer-centered and with more valuable interactive experiences. In addition, it allows for a shift in the brand management approach to a more omni-channel strategy.

In order to use Augmented Reality technology to improve customer experience it is important to understand in depth their expectations and needs. For some, a car is more than a means of mobility, it is a place where many memories are created, road trips and first school days, for others it remains as a symbol of freedom and power [22]. In that sense, emotion can't be dismissed, but it is important to also cater to the rational side of the consumer, by improving the explanation of the vehicle's technical aspects and price transparency.

The understanding of the decision-making process of the customer allows for a better development of tools to improve their experience and bring competitive advantage in this demanding industry.

The idea for this dissertation was put forward as a collaboration with Losch Digital Lab due to their ties to the automotive retail industry.

The company is a branch of an established Luxembourgish automotive company called Losch. Losch Luxembourg was funded in 1948 and is one of the pioneers in importing car brands and it is the largest car distributor in the country.

Losch Digital Lab dedicates itself to the development of adaptable, innovative and user centered software solutions to the digital transformation of the automotive industry. The solutions center around mobility as a service, electrification and the automotive retail process, specifically, management of garages and showrooms.

This dissertation was developed in the business environment, and serves as a exploration of possible solutions to the challenges that the automotive retail industry faces.

1.2 Statement of the problem

For the automotive retail industry it is important to enhance the customer experience: to be more connected, informative and interactive, this can be done through a deeper understanding of consumer behaviour and needs, as well as a change in brand management through innovative and interactive experiences.

It is a challenge to find a way to balance the utility with affectiveness in the creation of these experiences, to give all the necessary information about features and engineering while creating a connection and an experience that appeals to the buyer's emotional side. The emotional connection is valuable because it can diminish the technical faults and should be explored while trying to understand consumer responses.

> "WHATEVER one may think of the Mini Cooper's dynamic attributes, which range from very good to marginal, it is fair to say that almost no new vehicle in recent memory has provoked more smiles." BEHIND THE WHEEL/Mini Cooper, [64]

AR allows a combination between real and virtual, bringing digital components to one's perception of reality [63]. This enables the creation of experiences through participation, entertainment, and immersion.

Experiences are a way of providing sensory, emotional, cognitive and behavioural values that replace functional values [61] and occur as a result of an interaction.

For this dissertation, the aim is to study the viability of the use of AR experiences to better the sales and marketing of vehicles. Can AR, with its current technological constraints, create a seamless and enjoyable automotive retail experience? How do customers perceive this type of interaction?

1.3 Research aims and objectives

The first step is to define the problem space clearly, starting by understanding in depth Augmented Reality and analyse what's already been done in terms of Mixed Reality in the automotive retail and in other industries that can have similar objectives in terms of interactiveness with users, along with finding out how emotion is taken into account in the current marketing and the overall sales process in this industry. The next step is to develop and evaluate prototype solutions as evidence

in the analysis of Augmented Reality viability in this context in comparison with other types of interaction. In summary, the primary objectives of this thesis are:

- to study the application of different types of interaction in the automotive retail industry;
- to understand the car sale process, in order to identify opportunities and weaknesses;
- to recognize the user expectations and needs;
- to design prototypes of information display through Augmented Reality that consider the desires and prospects of users;
- to evaluate those prototypes;
- to analyse Augmented Reality in comparison with other interactions, and evaluation of suitableness for automotive retail.

1.4 Research questions

The literature research of this project focuses on four main subjects: Interaction and Design (with an introduction on human cognition and decision-making), Augmented Reality (definitions, technology and prototyping tools), Service and Marketing and the automotive retail current context.

Regarding Interaction and Design these are the questions the research should respond to:

- **RQ1**: What psychology concepts are important to understand?
- **RQ2**: What different design systems should be considered for this project?
- **RQ3**: What's the process that should be followed for the development and study of prototypes?

For the study of Augmented Reality:

- **RQ4**: What are the definitions of Augmented Reality and Mixed Reality?
- **RQ5**: How can Mixed Reality be displayed?
- **RQ6**: What are the advantages of each display?
- **RQ7**: What has been studied in terms of Human-Computer Interaction for Augmented Reality systems?
- **RQ8**:How can quick Augmented Reality prototypes be built?

Concerning Service and Marketing:

- **RQ9**: What type of service is auto retail?
- **RQ10**: What is a channel strategy?
- **RQ11**: How do you perform a marketing research?
- **RQ12**: What is experience Marketing?

After the literature research, and by gathering of data through the methodology laid out in the chapter 7, it is expected to answer the following questions:

- **RQ13**: What do the costumers value more in the car sale process?
- **RQ14**: In which moments of the sale process are consumers seeing AR being applied?
- **RQ15**: Do consumers react positively to the use of AR technology in this context?

1.5 Dissertation Structure

This dissertation is composed of a first part dedicated to the literature review which is divided into four topics: Interaction and Design, Augmented Reality, Service Science and Marketing and the Automotive Retail Industry.

The second part is dedicated to the State of the Art where it is explored the current applications of AR technology in the automotive retail industry.

This is followed by the Methodology section in which is laid out how the research was conducted.

The Methodology is ensued by Data Analysis in which is performed an in-depth analysis of the results of the research laid out in the Methodology.

In the end there is the chapter dedicated to the Discussion and Conclusions where the final thoughts, conclusions and future works are presented.

Chapter 2

Literature Review I - Interaction and Design

In this first part of literature review the focus is on Interaction and Design. Starting with a small introduction to human cognition through the understanding of knowledge, decision and perception. Then a comprehensive study on human-computer interaction, exploring various design disciplines that influence the design of AR systems for automotive retail such as: user-centered design for the creation of useful and meaningful user experiences; emotional design to develop emotional connections between the clients and the product; and, lastly, multimodal and tangible interactions design that influenced the AR design since it uses these two interactions.

The exploration of human-computer interaction in AR systems is later explored in the second part of the literature review dedicated entirely to augmented reality, in chapter 3 of this dissertation.

2.1 Human Cognition

Cognition is to think, whether it be more conscious, like solving a math problem, or more subtle, like interpreting sensory input.

The study of cognition focuses not only on thought but also in attention, perception, knowledge, language and memory and has striven to understand human behaviour and mental processes, inclusive decision-making [67].

In this chapter the concepts of knowledge, decision and perception processes are explored.

2.1.1 Knowlegde

Humans create mental models, which are not based not only on facts, but also on beliefs, and are defined as a model of what a person knows, or thinks he knows, about a system. These believes are the basis for his predictions for the system and he plan his actions accordingly. The more closely to reality the mental model is, the easier it will be for the user to interact with the system and so, designers strive to communicate the basic nature of the designs reasonably well in order to allow users to develop fairly accurate mental models.

Mental models, however are not fixed and stable and can be changed by experience, communication with others and even lessons from other systems.

2.1.2 Decision

There are two types of thinking, fast thinking and slow thinking. Fast thinking is more intuitive and automatic and aims to get to a "good enough" decision. While slow thinking tries to analyse the most variables as possible before achieving a conclusion.

Cognitive psychology strives to map mental processes, in the case of decision process, one accepted model is the Extended Information Processing Model [7], represented in the figure 2.1, a model similar to a computer where the human is seen as an input-output device: the information enters in distinct forms and then is perceived, processed, attended and stored internally, finally producing emotional or physical responses as an output.

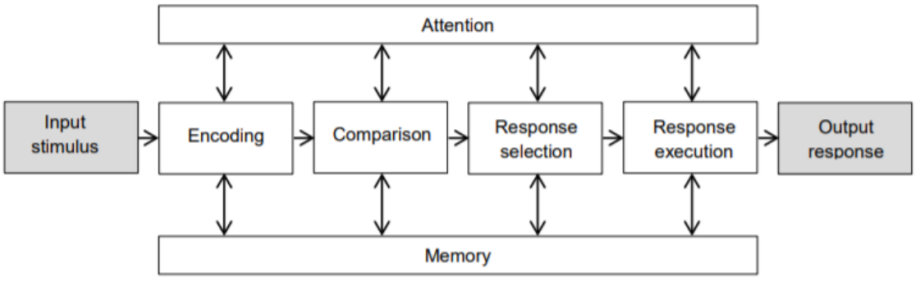


Figure 2.1: Extended Information Processing Model [7]

2.1.3 Perception

Gestalt is a german word that means "form" and it was chosen to name a theory based in the psychology of form and laws of perception and gives explanations as to why shifts in timing, spacing and form can have a great effect on the meaning of the information presented. The key concepts behind Gestalt theory are: "The whole is other than the sum of the parts." (Kurt Koffka), the whole is identified before the parts, our mind fills in the gaps, the mind seeks to avoid uncertainty and humans are good at recognizing differences and similarities [30].

In order to have a clear communication with users and avoid the creation of inaccurate mental models there were some principles created that designers should consider [16]:

- **Good figure, simplicity** (law of Prägnanz)
  "People will perceive and interpret ambiguous or complex images as the simplest form possible, because it is the interpretation that requires the least cognitive effort of us."
- **Closure**
  "When seeing a complex arrangement of elements, we tend to look for a single, recognizable pattern."

- **Symmetry and order**
  "People tend to perceive objects as symmetrical shapes that form around their center."
- **Figure/ground**
  "Elements are perceived as either figure (the element in focus) or ground (the background on which the figure rests)."
- **Uniform connectedness**
  "Elements that are visually connected are perceived as more related than elements with no connection."
- **Common regions**
  "Elements are perceived as part of a group if they are located within the same closed region."
- **Proximity**
  "Objects that are closer together are perceived as more related than objects that are further apart."
- **Continuation**
  "Elements arranged on a line or curve are perceived as more related than elements not on the line or curve."
- **Synchrony**
  "Elements that move in the same direction are perceived as more related than elements that are stationary or that move in different directions."
- **Parallelism**
  "Elements that are parallel to each other are seen as more related than elements not parallel to each other."
- **Similarity**
  "Elements that share similar characteristics are perceived as more related than elements that don't share those characteristics."
- **Focal points**
  "Elements with a point of interest, emphasis or difference will capture and hold the viewer's attention."
- **Past experiences**
  "Elements tend to be perceived according to an observer's past experience."

2.2 Human-Computer Interaction

"HCI involves the design, implementation and evaluation of interactive systems in the context of the user's task and work" [68]

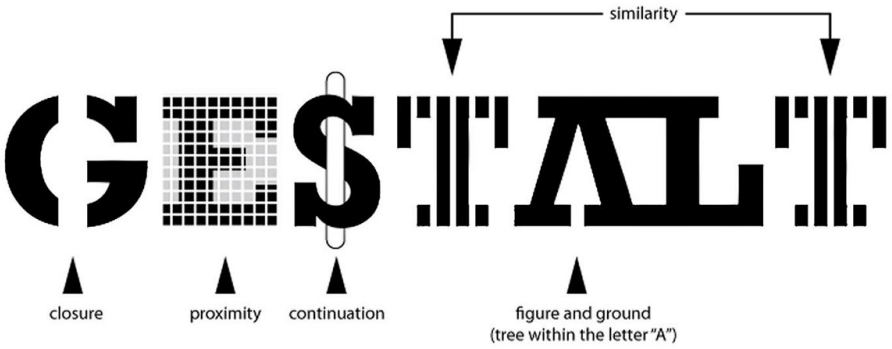


Figure 2.2: Example of some of the gestalt principles [19]

Human-Computer Interaction is a field that studies the interactions between humans and technology. It is influenced by art, engineering, design, linguistics and psychology, this last one being the main source of its methodologies, along with contributing and applying principles to interpret and establish models that predict human behaviour.

2.2.1 Five Stages of Design Thinking and Design Process

Software development and design use concepts of Human-Computer Interaction like human-centered design thinking activities and methodologies, in this context, they're commonly divided into phases of the development process [21].

For this project it was chosen a non-linear and interactive process commonly known as the five stages design thinking approach:

1. gaining an empathic understanding of the problem;
2. defining the problem;
3. conceptualizing it (brainstorm of ideas in order to find possible solutions to the problem defined in the previous step);
4. prototyping;
5. testing and evaluation of prototypes.

2.2.2 Overview of design principles

Human-Computer Interaction studies a wide range of disciplines as mentioned above, including design that is a broad concept and is applicable in many fields. The study of tangible and multimodal interfaces, user-centered and emotional design is beneficial for the development of an AR

application for automotive marketing and sales. The first two fields, multimodal and tangible interfaces are related to the different types of interaction with the real world, while user-centered and emotional design are linked to the purpose of the application, creating useful and meaningful experiences.

The **Gestalt theory**, mentioned in the previous "Perception" sub-chapter 2.1.3, had a great influence in the creation of some of these design principles.

For the **tangible design** the most important principles are the tangibility and materiality, physical representation of information, physical interaction and insertion in real context and situations. [34]

In terms of **multimodal user interfaces** - the use of different types of inputs and output of information, such as voice, gestures and many others – the two main values are to achieve an interaction close to human-to-human communication and increase strength in the interaction with complementary and redundant information.

The principles for **user-centered design** are:

- **Empathy** — empathizing with the people you're designing for helps grasping the context and complexities of the problem.
- **Optimism** — embrace the possibility of not knowing but keep searching for answers, and deeper understanding.
- **Iteration** — Iteration allows exploration and continuous learning.
- **Learn form failure** — accepting failures and critically analyse them in order to learn, since user-centered design allows for experimentation, embracing failure as a part of the process is very important.
- **Creative confidence** — creativity is a way of approaching and solve problems and doing it so in a confident way.
- **Embrace ambiguity** — at the beginning of the study start at a point of not knowing and open to the possibility of unusual solutions.

Emotional design is more complex, in the work of Don A. Norman, Emotional Design [47] it was defined three types of emotional response: Visceral, Behavioural and Reflexive, each one with different values [25]:

- **Visceral:**

  - Immediate reaction;
  - Look;
  - Feel;
  - First Impression;

- **Behavioural:**
  - Usability ;
  - Interactions;

- **Reflexive:**
  - Expectations;
  - Projections;
  - Reflect;
  - Storytelling;
  - Social;
  - Thought.

The in-depth definition and applications of these disciplines will be approached in the following chapters.

2.2.3 User-Centered Design

User-Centered Design is a problem-solving method that focuses on building empathy with the individuals you're designing for, aiming for an explicit understanding of environments, tasks, and more important, users.

In the work of Don A. Norman Design of Everyday Things [48], he considers that the two most important components of a good design are understanding and discoverability, the need to 'discover' or perceive the reason why an object exists and what it can and will be able to do.

2.2.3.1 Seven Stages of Action

As mentioned in the 2.1.2 subsection, models are often used to understand mental processes. For understanding user interaction process Don Norman created seven cognitive stages:

1. Forming the goal;
2. Forming the intention;
3. Specifying an action;
4. Executing the action;

5. Perceiving the state of the world;
6. Interpreting the state of the world;
7. Evaluating the outcome.

These steps are repeated in cycles, but when the goals established are not definite or clear they need to be divided into more precise actions.

At the end, the outcome of each action is evaluated, and it is analysed if the goal has been reached or if it needs reformulation.

The objective of following these steps is to guarantee that a product is intuitive and that the output is clear to the users.

2.2.3.2 Nielsen's Ten Usability Heuristics for Interface Design

In the studies of human-computer interaction Jakob Nielsen and Don A. Norman are seen as the fathers of human-computer interaction, even though Don A. Norman has his own principles of user interfaces, Nielsen's ten heuristics [46] are the most used in the evaluation of user interfaces:

1. **Visibility** — Should show system status and tell what's happening in the system.
2. **Match Between real world and the system** — The use of familiar concepts as metaphors and skeuomorphism to map the real and known concepts and the system
3. **Freedom** — Provide good fallbacks and allow for undo and redo.
4. **Consistency** — The interface should be uniform throughout.
5. **Error prevention** — Remove error-prone conditions and when they exist ask for confirmation before they commit to the action.
6. **Recognition instead of recall** — The information should be easy to discover, also, the user shouldn't have to remember from one part of the dialogue to another.
7. **Flexibility and efficiency** — Advance users' frequent actions should be sped up.
8. **Minimalism** — Provide only necessary information.
9. **Help** — Offer hints to guide users.
10. **Error Recovery** — Errors should be easy to understand and recover from.

2.2.3.3 User Testing and Usability Testing

The term "usability testing" is often used interchangeably with "user testing", however user tests can be run through focus groups and interviews, as well as eye tracking and, the mentioned, usability testing [43].

In general, user tests pertain to the study of the utility of the idea or product - whether users need the solution that was presented - and usability tests are an evaluation of the design decisions, in addition with helping to understand the effectiveness of use of a certain product.

Normally in usability tests it is asked of the participants to complete a set of tasks while observers take notes and ask questions. The data gathered in this type of tests can be quantitative or qualitative [42].

It is recommended the development of a plan of the test composed by the following elements [62]:

- Scope — what product you're testing, and how much of that product will it cover.
- Purpose — identification of concerns and goals of the test, the concerns identified will drive the scenarios that will be defined.
- Schedule — indication when and where you will do the test.
- Sessions — description of the sessions, how long will they take?
- Equipment — indication of the equipment used for testing, mobile, desktop, tablet, it may be important to mention browser version, or operating system. Equipment used to capture the test sessions should also be planned.
- Participants — indication of the number and type of participants and how the recruitment will be conducted.
- Scenarios — description of the tasks that you'll be asking the participants to perform.
- Metrics — as said above, the metrics can be quantitative and qualitative. It is important to define them:
  - Quantitative metrics: try to quantify the problem, are measurable (e.g., successful completion rates, error rates, time on task).
  - Qualitative/Subjective metrics: descriptive data gathered in pre and post test questionnaires but also after each task (e.g., observations about pathways participants took, problems experienced, comments/recommendations, answers to open-ended questions)
- Roles — inclusion of a list of the staff who will participate in the usability testing and what role each will play. (e.g., facilitator, note takers)

After the definition of all of these elements, it is important to choose the moderating technique [10]:

- Concurrent Think Aloud (CTA) — users think aloud as they interact with the product.
- In Retrospective Think Aloud (RTA) — after the session the moderator asks the user to retrace their steps.

- Concurrent Probing (CP) — requires the work on tasks, and the moderator can intervene when the user does something interesting.
- Retrospective Probing (RP) — at the end of the session the moderator can ask about the actions and thoughts of the user.

The pros and cons of each technique are presented in the figure 2.3.

Techniques	Pros	Cons
Concurrent Think Aloud (CTA)	• Understand participants' thoughts as they occur and as they attempt to work through issues they encounter • Elicit real-time feedback and emotional responses	• Can interfere with usability metrics, such as accuracy and time on task
Retrospective Think Aloud (RTA)	• Does not interfere with usability metrics	• Overall session length increases • Difficulty in remembering thoughts from up to an hour before = poor data
Concurrent Probing (CP)	• Understand participants' thoughts as they attempt to work through a task	• Interferes with natural thought process and progression that participants would make on their own, if uninterrupted
Retrospective Probing (RP)	• Does not interfere with usability metrics	• Difficulty in remembering = poor data

Figure 2.3: Pros and cons of each moderation technique [10]

2.2.4 Emotional Design

After some controversy around Don A. Norman's Design of Everyday Things [48] for the lack of consideration for emotion and the focus just on the logical side of the cognitive process, he then wrote Emotional Design, focused on the design of positive experiences for the user considering

the connections between users and objects, since "usable designs are not necessarily enjoyable to use" [47]. In his work, he laid out three emotional responses:

1. **Visceral** — relates to the appearance and aesthetics of the product, and the perceived value and quality it brings.
2. **Behavioural** — covers pleasure and effectiveness of use, or in other words, usability.
3. **Reflexive** — concerns rationalization and intellectualization of the product and the impact it has in the user's life after the use.

Concerning time, visceral and behavioural are focused on the present, the immediate perception of the product or experience, while reflective reactions are driven by future reactions and how will the person interpret it after-the-fact.

All these three aspects are important in the definition of consumer behaviour and understanding of how people connect to products, but are the visceral reactions that are vital in the creation of emotional experiences, while behavioural and reflexive have lesser effects.

2.2.5 Multimodal User Interface Design

To create transparent, flexible and efficient Human-Computer Interaction, the interest in interactions closer to human-to-human and in new ways of improving robustness of interaction grew so did the exploration of the combination of different types of input and output.

The following information is based on the work of Reeves et al. [56].

With the intention of creating efficient multimodal interactions it is imperative to take into consideration the maximization of human cognition and physical abilities. This means that designers must reflect on user's processing abilities, such as :

- Avoiding increasing cognitive load by not presenting unnecessary information in two different modalities.
- Reducing memory load by combining visual presentation and user manual input for parallel processing, and auditory presentation and user speech for attention and issuing commands.

Designers should also consider integrating the modalities with the system's functionality, user's preferences and context:

- Matching output and user input style;
- Improving collaborative speech with multimodal cues;
- Good temporal synchronization;
- The current system interaction state must be shared across modalities: supporting distributed interaction, multidevice and allow users to choose alternative modalities.

Multimodal interfaces should also be adaptable and take into account different contexts of use while being consistent. Input and output should share features and terminology and provide feedback when switching between modalities.

2.2.6 Tangible Interaction Design

Tangible interaction is an area that specializes in the interaction with interfaces and systems that are, in some way, physically embodied.

Tangible interfaces were thought to be a replacement of graphical displays to represent digital content through tangible objects and allow manipulation through physical interaction with the objects, however, with tangible augmented reality it was combined the display possibilities of AR with intuitive and interactive physical objects [34].

Tangible Augmented Reality interfaces should:

- Use physical controllers for interaction with digital content;
- Allow spatial 3D interaction;
- Support both space and time multiplexed interaction;
- Provide multi-handed interaction;
- Match physical constraints with the requirements of the interaction;
- Support parallel activity such as manipulation of multiple objects;
- Allow collaboration.

Chapter 3

Literature Review II - Augmented Reality

The second part of literature review is dedicated to the definition of key concepts around Augmented Reality, with the introduction of the Reality-Virtuality continuum followed by an exploration of Mixed Reality.

Considering the first part of the literature review with the introduction of Human-Computer Interaction, it is also explored in this chapter the study of Human-Computer Interaction of Augmented Reality systems: the different kinds of interactive interfaces, some design guidelines and prototyping tools.

3.1 Augmented Reality Concepts

Following the revolutionary work of Milgram, Takemura, Utsumi, and Kishino [41] that is most often used as a reference when discussing the taxonomy of Augmented Reality (AR), on a surface level, AR is defined in general terms as "augmenting natural feedback to the operator with simulated cues", or "a form of virtual reality where the participant's head-mounted display is transparent, allowing a clear view of the real world". This last interpretation of AR is too narrow since there's different ways of displaying AR, not just through Head-Mounted Displays (HDMs).

In other publications, like the survey of Azuma[6], it is considered that Augmented Reality systems are not restricted to the sense of sight but can be related to all of the other senses, not restricting its use to vision-based technologies.

Following this definition, an AR system:

- merges real and virtual objects in the real world;
- blends real and virtual objects with each other;
- runs interactively, in three dimensions, and in real-time.

There's also the mention of Mediated Reality or Diminished Reality, also considered AR, but that centres on the removal of real objects by overlaying virtual ones.

3.1.1 Reality-Virtuality Continuum

Augmented Reality is frequently associated with Virtual Reality (VR) — that is described as an environment that completely immerses the participant in a virtual world where the physical laws may not be applicable. VR is used in association with other types of environments where total immersion and complete digitization **do not** necessarily concern Augmented Reality and that fall in the Reality-Virtuality (RV) continuum.

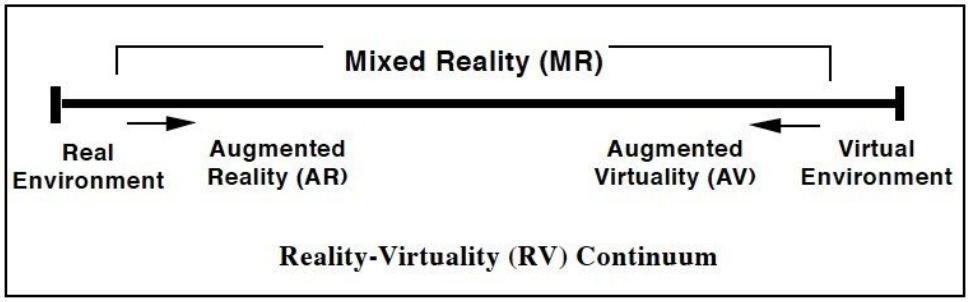


Figure 3.1: Reality-Virtuality Continuum [41]

This continuum is delimited by, on one side, a context consisted solely of real objects and, on the other side, a context consisted solely of virtual objects. The middle of this continuum is called Mixed Reality (MR), a context where real-world and virtual world objects are presented together in one display.

As mentioned there are different definitions that can be applied to the range that the reality-virtuality continuum covers, as shown in the figure 3.2

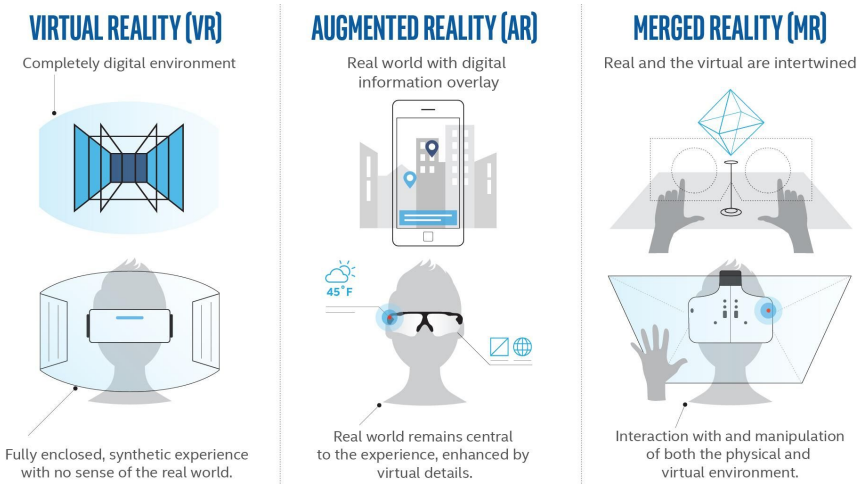


Figure 3.2: Reality roadmap according to Intel [17]

3.1.2 Mixed Reality

There are six classes of mixed reality interfaces:

1. Completely graphic but partially immersive settings in which real physical objects in the user's setting interfere with the digital scene;

2. Completely graphic display settings, either partially or completely immersive, to which video "reality" is added;

3. HMDs with see-through ability where computer-generated graphics can be overlapped, using half-silvered mirrors, onto real-world scenes. See figure 3.3;

4. HMDs using video, where the displayed environment should correspond with the immediate outside real world;

5. Monitor Based (non-immersive) video displays for example "window-on-the-world"(WoW) displays;

6. Video displays using immersive HMDs. See figure 3.4.

Figure 3.3: Optical see-through HMDs [35]

These interfaces have three main properties: reality, directness and immersion, presented in the table 3.1.

Figure 3.4: Immersive HMD [58]

Table 3.1: Mixed Reality Interfaces Properties

Properties		Description	Interface Class
Reality	Augmented Reality (AR)	Essentially real, based mainly in video.	1,2
	Augmented Virtuality (AV)	Mainly virtual, based primarily on computer graphics.	4,5,6
Directness	Optical	Real objects are observed directly through air or glass.	2, 4, 5, 6
	Video	Real objects are scanned and then resynthesized on a device.	1,3
Immersion	Exocentric	Not fully immersive.	5
	Egocentric	Immersive.	1, 3, 4, 6

There is a relation between these properties: for augmented virtuality, the immersion is focal to the experience and, in order to create that immersion, the observation of real objects is done through video. On the other side of the spectrum, augmented reality systems are exocentric, but can use optical and video to observe the real world.

3.1.2.1 Augmented Reality Systems

Diving into augmented reality specifically, the advantages and disadvantages of optical and video for the observation of the real world are explained in the table 3.2.

Table 3.2: Optical and Video Real-world Capture attributes comparison

Attributes	**Optical (mostly HMD)**	**Video (monitor based)**
Simplicity	Only has one stream of video, making the delay much smaller.	Has two streams of video, creating a longer delay.
Flexibility and brightness levels	The two light sources give a ghost-like appearance to the virtual objects and don't obscure completely the real ones.	Since it only has one light source the virtual objects can be better integrated with the real environment and it is easier to match real and virtual objects.
Resolution	Optical based is not as distorted as video.	Video bending limits the resolution, creating more distortion.
Field of view	Distortions of the user's real-world scene need to be changed optically since the system doesn't have a computed real-world image.	Distortions of the real-world can be easily changed digitally, creating a wider field of view.
Safety	The observer is always able to see the real-world.	When the power is cut off sometimes the observer is rendered blind to the system.
Real and virtual delay	There's the possibility of temporal discrepancies between real and virtual.	The video approach can match real and virtual delays
Eye offset	The viewpoint in the computer graphics model can be the eye's center of rotation and removes any obligation for eye tracking.	When cameras are not placed on the eyes precisely it creates an offset, needs eye tracking.
Accessibility	The market of HMD is growing but it still doesn't reach the monitor-based displays like phones and tablets.	Are overall more accessible to a wider audience.

Both types of systems face challenges in the alignment of the digital information with the real world. Currently, the tracking of the surrounding environment can be achieved through three types of technologies:

1. **Vision-based:**

   (a) Marker based — an easily detectable sign that can be detected using computer-vision techniques. See figure 3.5

(b) Feature based — detection of salient features like edges, corners, blobs or ridges in images.

(c) Markerless (MLT) — estimations of the current position, orientation and movement from captured images through the use of a calibrated camera that is capable of measuring the depth of each captured pixels.

2. **Sensor-based:**
   The tracking of the environment is based on information captured by sensors placed in the real world, even when lighting conditions are not perfect. The sensors can be magnetic, inertial, optical, acoustic and even GPS.

3. **Hybrid:**
   This technique combines vision and sensor-based tracking in order to make a more robust tracking approach.

Figure 3.5: Marker based Augmented Reality [44]

Regarding augmented reality systems technology, types of display are also an important attribute to categorise by, other than directness. These can be: head-attached, handheld and spatial.

With spatial displays, the user is not engaged in wearing any type of device and the image information is placed directly on physical objects. They can be screen-based, optical-see-through or projection-based.

Head-attached displays are attached to the user's head, the visualization can be achieved by attaching small displays or projectors in front of the eyes or even through lasers directed onto the

retina, with this, there are video-see-through head-mounted displays (HMDs), optical-see-through HMDs, head-mounted projective displays (HMPDs) and retinal displays.

Handheld displays are held by the user, whether they are mobile phones, tablets or PDAs and are the most accessible to the average user.

3.2 Human-Computer Interaction for Augmented Reality Systems

A big challenge of creating guidelines for augmented reality applications is the extensive number of systems and input/output devices that can be used. Even though visual interfaces are the most used, haptic and audio interfaces can't be ignored when creating general guidelines for augmented reality. However, it is still possible to study the different types of interfaces and analyse each of their constraints and values.

> "Unlike most other desktop interface and virtual reality systems, in an AR experience there is an intimate relationship between 3D virtual models and physical objects these models are associated with." [11]

Both Google and Apple created some design guidelines for augmented reality applications that are also laid out in this section.

3.2.1 Interactive Interfaces

In the work Advanced Interaction Techniques for Augmented Reality Applications [11] three types of AR interactive interfaces were defined:

3.2.1.1 Tangible

As stated in the previous quote, the connection between the real world and the overlay of AR objects can be the source of new types of interaction. The combination of intuitive physical manipulation of tangible user interfaces and the display possibilities of AR is called Tangible Augmented Reality. In this interaction, manipulations of physical objects are mapped one to one to virtual objects actions. Considering tangible design principles, the MagicCup interface [11] was created as a case study, a cup-shaped handheld AR input device that detects six-dimensional position and pose information. The basic interactions of this AR device are shown in the figure 3.6, in which human actions were assigned to the reactions of the virtual object. In the first action, the object is picked: it starts in one place, it is covered by the cup and then, when the cup is lifted, the virtual object is also lifted and can be moved.

These interactions need to make natural reactions of the virtual objects correspond to the real-world actions, allowing users to easily build the correct mental model, however, it has its limitations, since it only allows interactions with the virtual objects that the user can see.

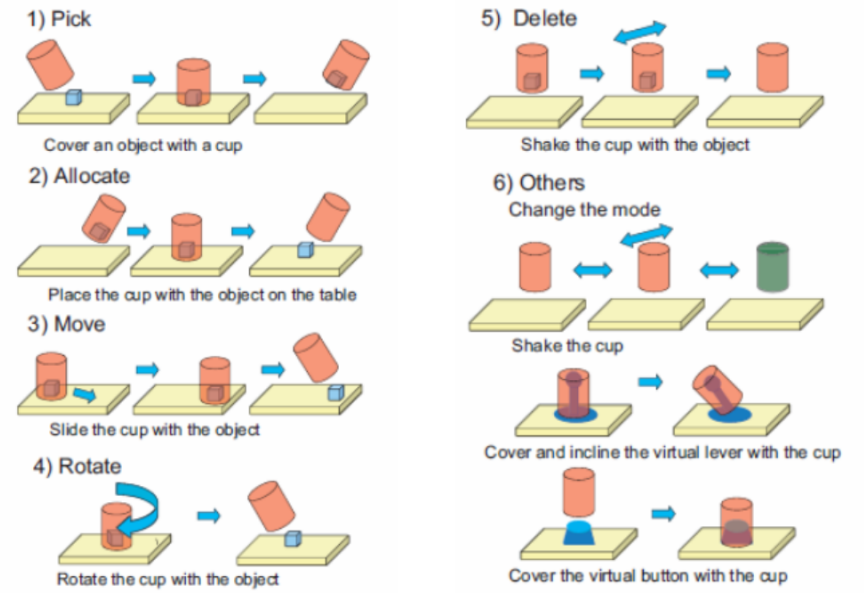


Figure 3.6: MagicCup Interface [11]

3.2.1.2 Mobile

Phones and tablets are the best examples of mobile interfaces, as they are characterised by limited screen resolution and graphics, as well as limited input options since these devices are normally one-hand held. This last point is important when thinking of how people will interact with the virtual objects and the overall AR scene.

Since the use of both hands is limited, solutions beyond touch are explored, for example, position and rotation of virtual objects have different challenges. In the study mentioned above it was concluded that, for position, the tangible object metaphor works for defining the position of the object (the users just have to move the device to where they want the object to be placed), while this same metaphor does not have the same advantage when users want to rotate the object.

In conclusion, while touch works for a lot of mobile interactions, the movement of the phone itself should also be incorporated in some actions.

3.2.1.3 Multimodal

Most interactions use a single modality input, however, in this study [11], the use of gestures and voice as forms of interaction with AR systems was proposed.

It was concluded that with just a tangible input, a paddle, users had more difficulties than when it was combined with speech commands, since it permitted them to choose which modality was best suited for them for each interaction, making it more intuitive. Also, the speech input allows the user to get access to objects that are not in his immediate field of view and, combined with other modalities, allows for a wider range of experiences.

3.2.2 Augmented Reality Design Guidelines

With the rise of mobile augmented reality applications, Apple and Google created their own development tools: ARkit and ARCore respectively. However, to help designers and developers, both companies created their own design guidelines of AR applications that are laid out in this section.

3.2.2.1 Google's Augmented Reality Design Guidelines

Google guidelines [29] start by defining the environment and space:

- **Physical space** — users should know how much space they need for the experience and, as the designer, the application should be created considering its use in different physical settings.
- **Virtual environments** — mapping the real world so that when the user moves the application can track the position in relation to the world around, creating a better combination between the digital content and the real world.
- **Continuous discovery** — the application should continuously improve the understanding of the real environment.
- **Environment limitations** — the understanding of some environments is flawed, lighting and texture can influence how well the application is able to recognize the surface characteristics. When that happens, the user should be alerted of what went wrong and pointed towards a solution.

Diving into the experience size, three types are recognized: tabletop size, room size and world size. The experience should fit the environment, and users should be aware of the ideal size and conditions for the experience. However, the experience size, whenever possible, should be responsive.

Movement allows for wider experiences, however, users often forget that they can move while interacting with AR, and so, movement should be encouraged. There are four ways a user can move:

1. Seated with hands fixed;
2. Seated with hands moving;
3. Standing still with hands fixed;
4. Moving.

For each of these cases:

- Let users know what movements will trigger the app;

- Guide them through the types and range of movement possible;
- Transitions between movements should be easy;
- Design for comfort. Try to avoid making the user do anything that's physically demanding, uncomfortable, or too sudden;
- Avoid the need for movement until it is necessary and let users ease into the experience.

In terms of accessibility, users should have different ways of interaction, for example, if they are not able to move around an object, they should be able to rotate it.

Even though the objective of augmented reality is to integrate digital content with the real world, users can be too immersed in the experience and not be aware of their surroundings and so, the application should:

- Alert them from time to time to check their surroundings;
- Don't make them walk backwards;
- Avoid long experiences;
- Allow resting positions;
- Let the user pause or save the progress, allowing the continuation of the experience in different settings.

Google also gives some suggestions on realism, focusing on what type of details, shadows, textures and normal maps work best for the 3D models, but also mentions that the digital objects should react to the real world.

In order to create an application with great usability, it is important to give feedback to the user as much as possible. During the process of surface detection, it is important to have smooth transitions, visual consistency and let them know about changes in system status in a timely and relevant way, highlighting detected surfaces, and alerting them if anything goes wrong.

The screen can be divided into 3 stages: downstage, closest to the user, upstage, farthest to the user and center stage, the most comfortable viewing range. These stages are important to perceive depth, scale and distance in the desired way.

In object placement users should be guided into a comfortable viewing distance and have destination points to help them understand where the object will be placed. There are suggestions on when to use automatic placement and manual placement. When using manual placement tapping or dragging objects are the best interactions, always with guides and feedback. Anchoring is also a possibility, when anchoring an object to a scene, the object stays in place even when the user moves around.

As for object manipulation: selection, translation, rotation and scaling, it is explained how each interaction should be designed and which type of gestures work best for each manipulation.

Their suggestions on interaction are divided into UX and UI. In the UX part they recommend smooth transitions between 2D screens and AR, the use of visual and auditory cues for off screen exploration, avoid haptic feedback, include depth collisions and allow the user to reset the scene. As for the UI, the experience should be immersive and interruptions like pop ups must be avoided. Persistent 2D overlays, like menus, also prevent the user from a full immersive experience. Controls should be easy and intuitive to use, the mechanics should be explained all at the same time, but as the user interacts, and explores, text instructions should be avoided as they break the immersivity of the experience. Familiar patterns and visual cues are preferred. Provide support for landscape and portrait mode and be clear on why the application needs certain permissions.

3.2.2.2 Apple's Augmented Reality Design Guidelines

Apple's guidelines [4] touch on different aspects of the AR experience design and are overall more concise in their explanations than in the guidelines by Google.

- Offer AR features only on devices that support them;
- The screen should be mostly dedicated to the display of the real world and the digital objects and not be cluttered by controls and information;
- Strive for convincing illusions when placing realistic objects like furniture;
- Take into consideration the real world reflected on reflective surfaces on digital objects;
- Use audio and haptics to enhance the immersive experience;
- Minimize text;
- If additional information or controls are necessary, consider displaying them in screen space (fixed to a consistent location in the virtual world or on the screen);
- Consider using indirect controls (2D controls displayed in the screen space, preferably translucid and easy to reach without adjusting the hold) when you need to provide persistent controls;
- Anticipate that people will use your app in a wide variety of real-world environments;
- Consider users' comfort;
- Introduce motion gradually;
- Consider users' safety;
- Use coaching views without unnecessary UI;
- Offer custom coaching experience;
- Show people when a surface is located, and an object is placed;

- Integrate placed objects immediately into the AR environment;
- Users should be guided towards offscreen virtual objects;
- Let people use direct manipulation to interact with objects when possible;
- Object manipulation should use standard and familiar gestures;
- Keep interactions simple;
- If you must display instructional text, use approachable terminology;
- 3D hints for 3D contexts;
- Make important text readable through screen space;
- Let people reset the experience if it doesn't meet their expectations;
- Suggest possible fixes if problems occur.

3.2.3 Prototyping Augmented Reality

There's a lack of assessment of AR systems usability, since most of the discussion regarding these type of systems has been concerning their technological properties, and not how to design interactions with AR systems. Most development tools have been focusing in passive viewing experiences and virtual information conveyed in the real world, normally with a marker-based tracking. In this sense, there's a difficulty in creating fast and flexible prototypes with different types of tracking, because, for now, some knowledge of programming, 3D modelling and interaction design is required.

Even though AR can come in many different interfaces, this section will mainly center on monitor-based video displays, like tablets and smartphones, since they are less expensive devices and, even though the tools found targeted that type of interface, they were scarce and missing important features to design AR applications with complex interactions.

It is possible to achieve low fidelity prototypes using paper or blocks to represent objects in a 3D space, and, in order to add motion it can be used video editing tools. These solutions are easy to access and allow for rapid adaptation, in addition to force to always test in context.

For higher fidelity prototypes, there are a few tools that allow for a flexible AR prototype creation:

Adobe Aero [1], allows for the creation of some simple interactions with 3D models, but those are limited to animated models, this means that for simpler models without animation, creating other types of interaction is not possible with this application. Its features are limited to placing the object in the world and taping or drag it to trigger an animation.

Torch [66], created with the propose of design AR applications, is definitely one of the most complete tools, since it is easy to place 3D models and to create screens - similar to the design

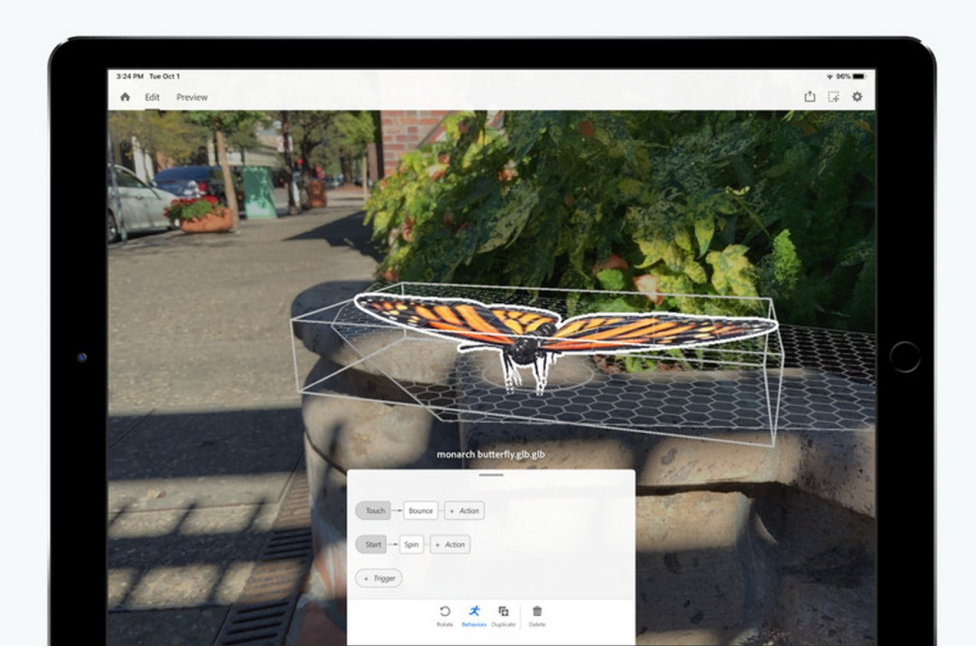


Figure 3.7: Aero interface [1]

process in Figma and Adobe XD, tools normally used in the design of web and mobile applications. Nonetheless, it is limited to iOS and lacks the ability to stick elements to the screen. This last problem is present in most tools, however Torch allows for the creation of simple URLs that can be called on 2D interfaces of Figma or Adobe XD.

Vectary [69] is a very complete tool, not only allows for 3D modelling and some 3D animation, but it creates elements that are easy to place in web based applications as a fully interactive 3D models with an AR icon. However, when clicking on the AR icon it opens the camera and just places the object created on the screen space, lacking interaction in that mode.

ViewAR [70] it is simple and effective but restrained by templates. Even though those templates are already responsive to all major platforms and come with explanations on how to interact with the scenes, they are still too constraining in terms of design. Nonetheless, of all the tools, this is one of the few with stick-on-screen possibilities, great for navigation and information placement.

Spark AR Studio [26] has many AR capabilities even though it is mainly marketed as a tool to create some of the most known applications of AR, Facebook and Instagram filters, yet, in terms of placing objects in a fixed position, it is not reliable. It also lacks the possibility to create relative complex interactions.

Reality Composer [3], created by Apple, see figure 3.10, is an application that uses ARKit but that doesn't need any programming knowledge. Similar to Torch, it is possible to create different

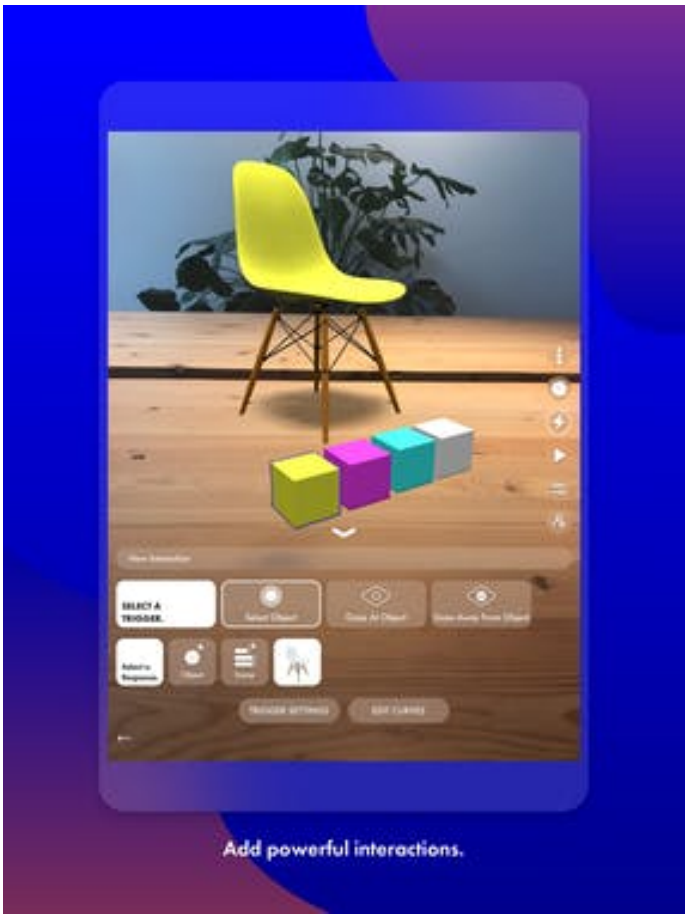


Figure 3.8: Torch interface [66]

Figure 3.9: Vectary interface

screens that can be connected. It only supports one type of file format, USDZ, but it is the more stable of all applications. Reality composer also allows for some alterations in the models and has more interactions than the other solutions.

Regarding programming frameworks its offered ARCore, a tool by Google, and ARKit, by Apple, both can be used to create mobile experiences, however both requires programming knowledge and for that reason are not the best solutions to quick, simple and adaptable prototypes.

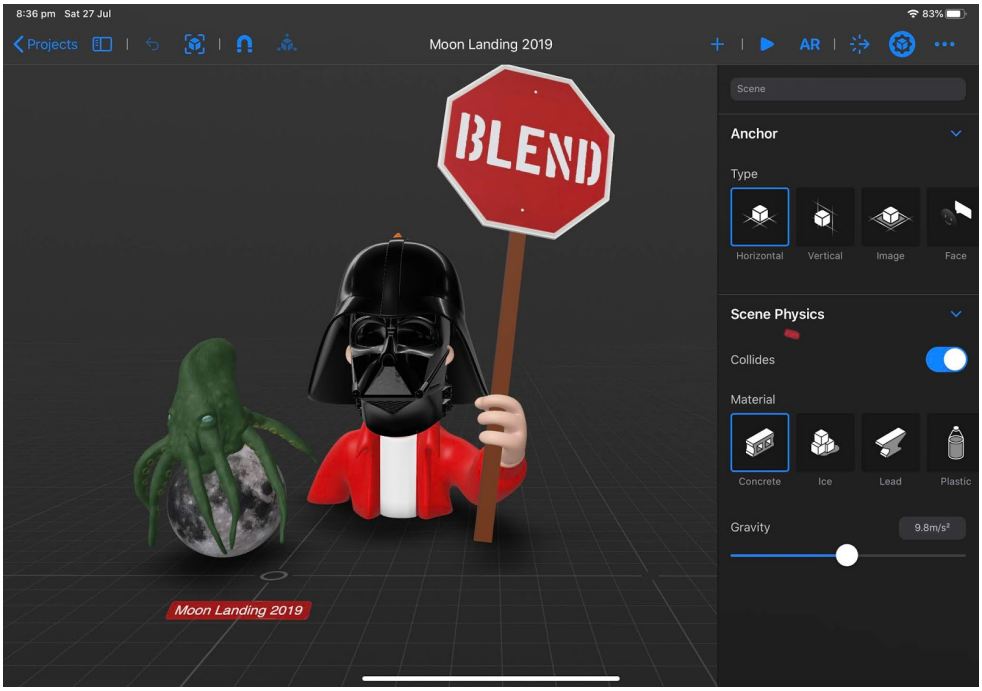


Figure 3.10: Reality Composer interface [32]

Chapter 4

Literature Review III - Service Science and Marketing

This section presents an overview of service science, as well as an introduction to some key marketing concepts. It is also explored experience marketing.

4.1 Service Science

Service Science or Service Science, Management, Engineering and Design (SSME) can be defined as an interdisciplinary approach to the study, design, implementation and innovation of service systems.

Service is co-creation of value through communication, planning and other types of interaction between distinct entities, individuals or firms [39].

The disciplines that are dedicated to the study of services are: marketing, by distinguishing the sale of goods from the sale of service activities; operations, through the understanding that the production processes and service processes needed to be built differently; economics, with the differentiation between tangible goods and intangible services; and even, computer science, with web-services and service-oriented computing.

Services can be classified by the amount of contact with the costumer: Pure services have high contact with the customer, some examples are schools and health centers. Mixed services, examples are repair shops or police stations. Quasi-manufacturing services have low contact, for example postal services and wholesale.

It is important for a company to analyse their contact strategy, since the less contact with customers there is, the bigger the freedom to design efficient production procedures is. This can be done by answering the following questions [39]:

1. What is your current contact mix?
2. Can your operations be realigned to reduce unnecessary direct customer service?
3. Can you take advantage of the efficiencies of low contact operations?

4. Are you appropriately allocating contact and no-contact tasks?
5. Can you enhance the costumer contact you provide?
6. Can you relocate parts of your service operations to lower your facility costs?

The correlation between each production procedure and customer contact is shown below:

- Facility location — high contact should be closer to costumers.
- Facility layout — high contact services must focus on the customer's needs and not only on improving production.
- Product design — high contact operations should incorporate the environment of the service.
- Process design — with low contact systems the customer is not directly involved in the process, while high contact systems have a direct and immediate effect on the customer.
- Worker skills — in high contact services the workers are part of the service product and have to be able to interact with the public, while low contact services normally required more technical skills.
- Quality control — in low contact services the quality control is fixed and measurable, while in high contact the quality control is more variable.
- Capacity planning — high contact capacity must be set to match the peak of the demand.

The evaluation of service quality normally is done based on the framework SERVQUAL which asserts that costumers form global impressions of the quality of the service provider based on confirmation assessments of five dimensions: reliability, assurance, tangibles, empathy and responsiveness.

For complex services with high risk, consumers prefer personal channels, while for simpler or known services, costumers tend to use self-service channels that are more impersonal.

Brand image is directly linked to customer loyalty, as in the retail industry, customers' brand loyalty often outweighs their store loyalty. For example, this has been confirmed in the automotive industry by Bloemer and Lemmink [14] and Herrmann and Huber [33]. Bloemer and Lemmink [14], who found a positive relationship between brand loyalty and dealer loyalty in their regression model. Even though, brand image is the strongest driver of customer loyalty, it is then followed by product quality and service quality [20].

4.2 Marketing

> "Marketing is the activity, set of institutions and processes for creating, communicating, delivering and exchanging offerings that have value for customers, clients, partners and society at large." [2]

In other words, Marketing can be defined as the promotion of products or services of a company for a target market. Although there are different approaches to this promotion, a marketing plan should consider these elements:

- An overview of the business advertisement goals;
- The description of the current marketing position;
- Key performance indicators that will be tracked;
- The description of the target audience and customer needs.

One key concept to understand is the marketing mix - the set of tactics used by a company to promote its product or brand, being the most normally used the four P's: Price, Product, Place and Promotion, with the addition in recent years of other three P's: People, Process and Physical Evidence.

1. Price — What is being advertise should match the financial cost of it, creating a link between the perceived and the real value.
2. Product — The product should be what the consumers expect and fit their needs.
3. Place — Place decisions indicate where the product or service is sold and how it is sent to the market.
4. Promotion — Promoting is defined as the messages that the company sends to consumers in order to influence them to buy their product. This achieved by explaining why they need it and why they should pay a certain price.
5. People — The employees that contact directly with consumers have a great deal of influence on their experience while buying the product.
6. Process — Focus on the delivery of the service to the costumer.
7. Physical Evidence — The physical evidence refers to the material part of a service, that normally offers intangible products.

4.2.1 Channel Strategies

A distribution channel is a set of organizations used to make a product or a service available. The distribution can be one of two, direct or indirect. The direct is when the producer sells the product or service directly to the consumer. Indirect is when there's one or more intermediaries in the distribution process. When referring to a service there's also the service interface defined as:

> "any place at which a company seeks to manage a relationship with a customer, whether through people, technology, or a combination of both." [55]

In order to design a marketing channel system [52]:

1. Analyse customer needs, quantity of purchase, waiting and delivery times, convenience, product/service variety and add-on services;
2. Establish objectives and constrains;
3. Identify major channel alternatives:
   (a) Types of intermediaries;
   (b) Number of intermediaries — exclusive distribution, selective distribution, intensive distribution;
4. Evaluate channel alternatives:
   (a) Economic criteria;
   (b) Control issues;
   (c) Adaptability criteria.

Channels often cater to different types of costumers, and, in order to reach the target audience, companies must combine various channels, opting mostly between a multi-channel strategy or an omni-channel strategy [8].

4.2.1.1 Multi-channel

As the name indicates, multi-channel strategy offers a multitude of channels at the disposal of the costumer with consistent service across channels. Identifying which channels are more suited for each costumer and for each component of the service is a focal point for this strategy.

4.2.1.2 Omni-channel

An omni-channel content strategy provides a fully integrated experience, putting the customer at the center of that experience where all the channels communicate between themselves [24]. In the case of retail, marketing and sales are joined through every channel available. For example, while at the physical store, the client can get information by scanning a code or redeem promotions found on social networks.

4.2.2 Marketing Research

When making a marketing decision it is important to carry out a search in order to better frame the problem and critically appraise the solutions proposed. To do so, there's a six-step process:

1. Defining the problem and research objectives;
2. Developing the research plan;

3. Designing data collection method and forms;
4. Designing samples and collecting data;
5. Analysing and interpreting the data;
6. Presenting the findings.

In the second step of this process it is important to determine what type of research is being conducted.

Table 4.1: Types of marketing research

Type	**Description**	**Instruments**
Exploratory	It is a qualitative form of research, normally used when the topic, problem and hypothesis are not well defined. Aims to gain broad insight and narrow the focus.	Secondary research, focus groups and interviews
Descriptive	To measure in a quantitative way a specific topic, used when the research calls for more detailed data.	Surveys
Causal	Used when trying to establish a causal relationship - cause and effect - between two or more variables.	Experiments in a controlled setting (test markets)

4.2.3 Experience Marketing

Experience Marketing aims to differentiate the brand's offerings through consumer's experiences. However, it is difficult to define "experience" since it is such an abstract and complex concept.

> "By experience Carbone and Haeckel (1994) mean the "takeaway" impression formed by people's encounters with products, services, and businesses – a perception produced when humans consolidate sensory information. Tarssanen and Kylänen (2007) define experience as "emotional experience that can lead to personal change ", Pine Ii and Gilmore (1999) as memorable events, and Pitkänenand Tuohino (2006) as affective events that have a strong impact on the perceiver." [57]

Either way, experience marketing proposes to better the consumer's experience quality, appealing to the logical and cognitive side as well as the emotional side of the costumer. In the work of Bernd Schmitt[60] he defined five different types of experiences:

1. Sensory experiences;
2. Physical experiences;

3. Creative cognitive experiences;
4. Social-identity experiences;
5. Behaviours and lifestyles.

The marketing mix can result in the creation of such experiences, bringing value to the consumer.

Chapter 5

Literature Review IV - Automotive Retail Industry

This chapter presents the factors that have more influence in the context of the automotive retail industry, along with an explanation about the shifts in the current mobility paradigm that shapes the future of this industry.

5.1 Automotive retail context

The automotive retail remained almost immutable through several decades, nevertheless, the environment in which it is inserted is rapidly shifting, forcing a drastic shift in the entire automotive industry.

For many years, the automotive industry was “organized around a structured, homogenous supply chain that evolves in line with manufacturers’ externalizing policies. Its sequence organization is firmly anchored in the hierarchies between suppliers, manufacturers and distributors" [28]. Normally the vehicles were wholesaled by Original Equipment Manufacturers (OEMs) to dealers, this transaction was financed by finance organizations, and the vehicle was then delivered to the dealer by third party logistics companies. The dealer then sold the vehicle to the customer that finances it through the bank or the finance organization [23].

Due to a fast change in the mobility paradigm, the structure mentioned is gradually being dismantled. Some of those changes are represented in the figure 5.1 as drivers of change of the mobility paradigm. In the next chapters some of those drivers will be explained.

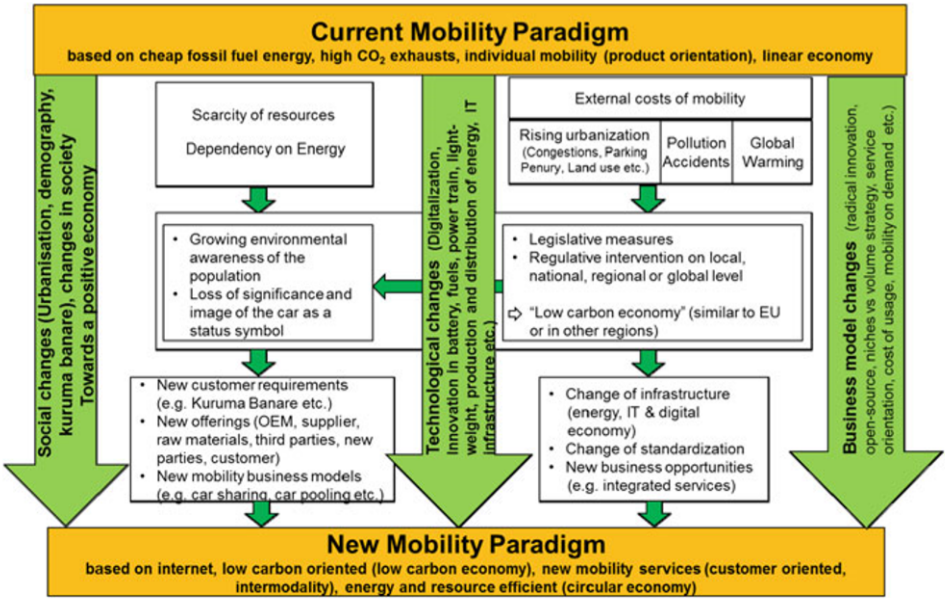


Figure 5.1: Drivers of the new mobility paradigm, Source [5] *The Automobile Revolution- Towards a New Electro-Mobility Paradigm*

5.1.1 Customers and Expected Value

Every generation of costumers has a different set of values that need to be considered by manufacturers and stakeholders of the industry as requirements and usages.

On one hand, generation X and Baby boomers still have a strong emotional connection with vehicles, they value the status and social image over cost, often putting themselves into financial debt. They are also less favourable to alternative ownership solutions like car sharing, carpooling and renting, preferring personal vehicles.

On the other hand, the newer generation of automotive consumers, the generation Y, that includes 25 to 35 year-old, has introduced different societal values and contributed for new types of mobility that are more relaxed, rational and sustainable.

This generation lives "in a system of constant communication dominated by new usage types; they expect to use objects and products for free or almost nothing, enjoy open access to knowledge, technologies and, in particular, consider that ownership can be shared or exchanged and is not a symbol of social success", [5].

The bond with vehicles is drastically different from the older generations, as mobility is more important than power. The car is no longer a social symbol and real-time access to information and being constantly connected to their environment is essential. In summary, a car can't be seen as an end in itself, but a tool for gaining mobility, shifting the preference of vehicle ownership to vehicle access.

Still, a high percentage of Gen Y has plans of buying or leasing a car in the following years, even more than the other generations [59], however their decision is impacted by complex factors

such as:

- affordability;
- maintenance costs;
- environmental concerns;
- if the lifestyle needs are met by walking, public transit, bikes or other two-wheel motorbikes.

The value of each factor is variable between countries, while in the US affordability is listed as the main reason for not owing a car, in other countries the factors are outside of the control of automakers. In Germany, the primary motive for not owning a car is the lifestyle needs which are already being met by walking or public transit. In China and Japan, inconvenient and/or expensive parking is registered as the primary reason as to why many Gen Y consumers are not interested in buying a vehicle [59].

Also in Japan, a movement called *kuruma banare* has been growing since the 1990's, "de-motorization", describes an attitude towards mobility without personally owning a motor. This movement came as a result of a convergence of forces: an aging population, traffic congestion, infrastructure challenges and convenient access to alternative modes of transportation. This trend is also an increasing threat in the US and European markets.

Yet, it is still important to note what makes this younger generations want to buy a vehicle, represented in the graphic 5.2. The primary factor in most countries is less expensive vehicles but also more affordable payment or lease options and more fuel efficient vehicles, since this is the more environmental conscious generation of automotive consumers to date. The search for less financial stress and more economic stability is mainly due to growing up in one of the deepest and prolonged recessions in recent economic history.

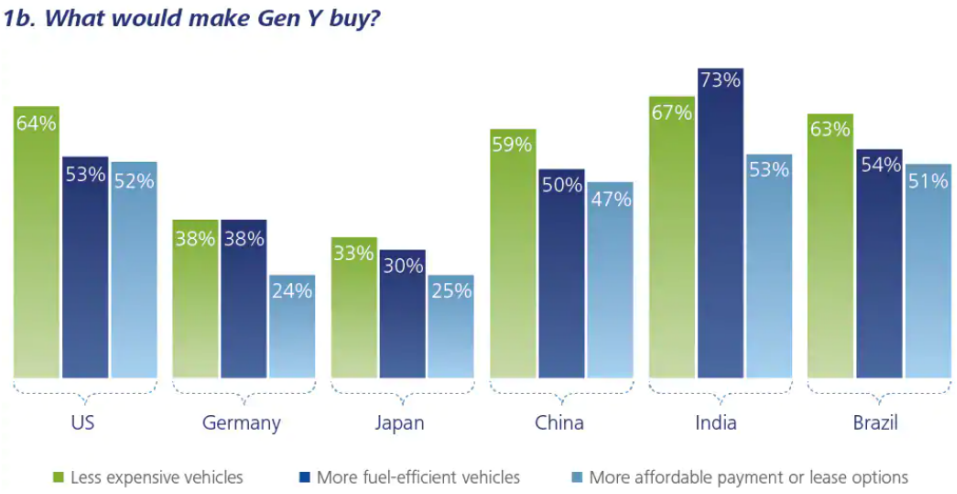


Figure 5.2: What would make Gen Y buy?, Source *Delloite* [59]

5.1.2 Technological innovations

Technological innovations are constantly shaping the automotive industry. By optimizing the combustion engine, through cylinder deactivation, variable valve train, turbocharging and downsizing, utilization of exhaust gas energy, direct injection, new combustion, variable compression etc., the current powertrain technologies are being improved in order to become more ecological, not only due to legal pressure, but also since costumers are more concerned with being more environmentally conscious.

Another big technological shaper for the automotive retail industry is digitalisation.

> ”Increasing returns (economies of scale, economies of scope), network effects and lock-in effects are the keys of this new economy [27] and which will reshape the industry structure [54].” [5]

For this industry in particular, digitalisation is a means of providing services that combine bicycles, scooters, cars or trains in a single system, all for the sake of the customer as the central figure of the services (customer centralization). These types of services are being created as a response to the rivalry between OEMs, as well as the current industry's value chain, developing competing mobility eco-systems.

5.1.3 Mobility Services

As mentioned in the previous section, auto retail industry is being directed towards a more customer-centric approach along with being influenced to create more mobility services. These mobility services are able to reduce transaction costs and, due to the nature of sharing, improve the time of their use, minimise the use of energy, materials, place, etc.

Ride sharing can help to improve the efficiency of the driving time by sharing empty seats in a car. The costs of the ride are shared between driver and passenger and, sometimes, the platform. The number of users is important due to the network effect, an enlargement of the network has a direct positive impact for all users. Dynamic ride sharing means that services can arrange shared rides on a very short notice. Besides these direct network effects, there are also indirect effects (Clement and Schreiber, 2013) like user ratings or reputation which lead to an increased quality with each additional user [5].

Renting and leasing, recent mobility solutions with growing adhesion, are both contracts made with dealerships, where a monthly payment is made and can be cancelled at anytime, allowing a flexible ownership of a vehicle. These services differ in:

- Duration — leasing options are seen as long term renting, normally lasting between 12 months and 96 months.
- Maintenance — with renting the maintenance is covered by the dealership, while the terms of a leasing contract regarding repairs are negotiable.

- Ownership — at the end of the leasing contract the client can choose to renew the contract or buy the car. If they choose to buy the car it is possible to use the money spent during the contract to finance part of it.

These solutions brought flexibility to the financial solutions offered at dealerships, adapting to different consumer needs and lifestyles.

Chapter 6

AR and MR in the automotive industry

6.1 Introduction

In the state of the art we analyse the current and past applications of AR and MR in the context of the automotive retail industry and their success. Whether it be in bringing better experiences for consumers or improved productivity.

In the automotive retail industry AR solutions are used in interactions with customers to enable:

- product personalization;
- product visualization and experience;
- speeding up the sales process.

These three applications of the technology consider the balance between providing information to the client in an easy to comprehend manner and connecting with their emotions. Seeing that, some examples try to bring the car into the clients life before the purchase, in order to create an emotional bond by providing an experience through a full-scale visualization of the vehicle anywhere at any time. Something to note, the AR display used in most of these interactions is mobile, allowing for outside-dealership experiences, focusing on accessing the desired information and customization anytime, as well as bringing the product to the everyday life.

However, AR is also used as a tool to help in the maintenance and inspection of vehicle after the sale. In the hands of the consumer it can be a quick repair guide, while in the context of garages and repair shops it can help as a management and inspection tool, or even an assistant for more complex repairs reducing the mistakes made by technicians.

6.2 Product personalization

In terms of product personalization, AR allows the instant presentation of any alterations, like color and finishes in the chosen car, whether it be in the dealership or at home. This diminishes

the apprehension in asking to see all the options to the dealer and asking for a budget plan for each one. Giving the customer full control and independence to “play around” with the customization, while also immediately providing prices, is especially important since it brings more transparency to the process.

6.2.1 Audi City

Audi uses AR in their dealerships in a completely disruptive way, being the first brand to have a car showroom without cars - Audi City. They present their entire model range using virtual technology throughout, blending the advantages of the physical dealership with digital innovation. Audi City also acts as the main innovation lab for sales activities digitally connected.

On top of the services normally offered at a conventional dealership, they aimed for an experience without pressure. They’re open to visitors wanting to explore and find out more information on the world of Audi or the technologies and services, as well as to fully customize their dream model and order it.

> “Using innovative media technology, fans and customers of the brand can customize their dream Audi from several hundred million different possible configurations, then experience it on almost 1:1 scale on floor-to-ceiling mega-screens“ [37]

These screens, shown in the figure 6.1, are projections surfaces and are called the powerwalls. These are used to display all the Audi models with all the different options of personalization in as much detail as possible. This allows for the customer to see, in real-time, the alterations he wants with a lot more precision than in a traditional showroom. The powerwalls can be connected as one big screen used in room-filling broadcasts of events. These events and experiences open new opportunities for the brand to be present in other contexts and be part of the urban life.

> "With Audi City, the brand is successfully developing premium car sales to the next level and is conquering new customers for the Four Rings. The response at the locations already opened confirms just how successful the concept is." [37]

6.2.2 BMW

The BMW IVisualizer was used to personalize the interior and the exterior of the BMW i3 or i8 through a smartphone, by using the discontinued interactive technology called Tango. The personalization could then be saved and sent to social networks or to a BMW showroom.

> ”“During our pilot, people had great fun exploring the car, even ducking down their heads as if there really were a roof there,” Castronovo said. “It’s that level of detail which means this technology offers the customers real added value,” he continued.” [9]

Figure 6.1: Audi City [37]

BMW also created a similar application for the 7 series, a 3D data model specially optimized for mobile, without 3D glasses or additional hardware. They can move freely around the vehicle, choose colors in the paintworks and gaze at the details of the full-size 7 Series. In addition, the Visualiser was connected to the BMW Individual app, which helps to create a seamless customer journey. [15]

6.3 Product visualization and experience

AR provides several means for customers to experience the vehicles before buying them, by bringing the car anywhere through their phone camera and see the features as if they were inside of the physical car, thus bringing the showroom experience everywhere and making the car tour experience more accessible.

6.3.1 BMW

As mentioned before, BMW has some AR base solutions that aim to expand the dealership experience by allowing the client to get familiar with the vehicle before buying it. Those solutions allow the user to experience the car anywhere, as well as to explore the vehicle inside and its features.

> ""Our research shows that consumers are seeking improved use of technologies like augmented reality during the car-buying process to make the online-offline experience more compelling," said Christina Raab, managing director in Accenture's Automotive

practice. “BMW i’s use of Tango technology and its integration with sales outlets and existing configuration tools is helping create the seamless multichannel experience customers are seeking.”” [9]

6.3.2 Jaguar AR and VR applications

Jaguar created a tour, available by clicking a banner ad on Android phones or desktop browsers. It lets consumers involve themselves in a full view of the inside of the Land Rover, which is represented in the image 6.2. Allows the users to see their surroundings from the inside of the car, while also being able to explore it and click on some hot-spots to get information about the vehicle.

Figure 6.2: Jaguar Land Rover Ad [12]

Jaguar chose not to create a complete mobile application to do so, instead, they just asked for the permission to use the smartphone camera, because, in their opinion, it would have made for a more “clunkier process”, said Taylor Hoel, media specialist at Jaguar [12]. On another hand, this can create an intrusive experience for users, seeing that they need to click on the banner ad, approve its access to their camera and, just then, finally experience the car through AR.

Other AR solution by Jaguar was the Discovery Land Rover model being shown, in 2015, using Durovis Dive headset with an Iphone 5S. They created an experience that granted customers a virtual tour of a full-size 3D model of the car, opting for a more immersive showroom experience.

6.3.3 Porsche’s 718 Boxter Ad

The Porsche’s 718 Boxter print ad [13], was made by the same company of the Land Rover ad: users scanned a collection of adverts and could read about the performance features, discover car

interiors and customise colours. They also added a layer of gamification to usual advertisement techniques by encouraging users to race and record their times around the Gotthard Pass track.

6.4 Speeding up the sales process and increase conversion

In order to increase conversion and speed up the car sales process, consumers should have access to comprehensive information about features and engineering. This can be achieved through mapping of the product and making it see-through or showing details and how it works in a more accessible way.

6.4.1 Toyota AR

Toyota AR allows for a different exploration of car features by seeing inside the model, using object recognition and AR it creates an overlay that shows the inner workings of the drivetrain onto physical vehicles, and each individual features are highlighted with animated AR scenes, ranging from showcasing how the shocks look like as the vehicle rolls over a rocky surface, like in the figure 6.3, or how the snorkel air-intake works as it enters a cloud of dust, helping consumers better understand how the system works and keep them engaged [31].

Figure 6.3: Toyota AR solution [31]

An interesting point of this solution is the use of custom made viewer stands that, even though are stationary, support a viewer able to move in any direction, allowing the user to experience all that the Toyota TRD Pro display has to offer, both digitally and physically, as displayed in the figure 6.4.

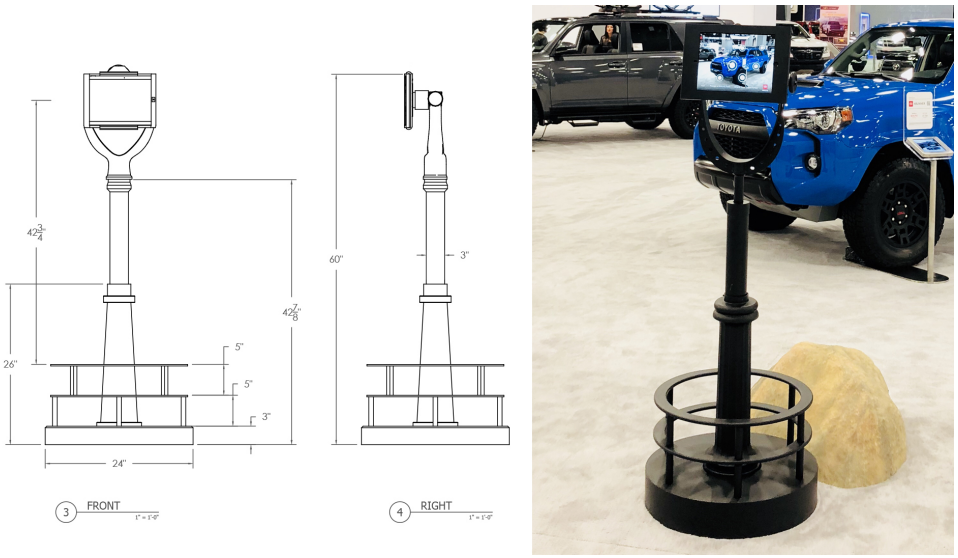


Figure 6.4: Toyota Viewer Stand [31]

6.4.2 Hyundai AR

Hyundai opts for an AR application that runs on iPads and is used by the salesperson to show the dealership visitors the car's safety characteristics, as well as colors and accessory options.

> "The platform's AR features anchor to a sticker on the vehicle's driver-side door. The app overlays a 3D model of the car so that users can change its colour and wheel types, and view animations showing features such as lane-keeping assist system. At the back-end the platform also provides Hyundai with insights into its usage." [49]

6.5 Car repair and maintenance

As mentioned, there are car repair and maintenance solutions towards vehicle's owners or technicians.

The solutions made towards owners are mainly mobile and give directions to help with simple maintenance tasks and can serve as a substitute to dense instruction manuals.

AR solutions towards technicians are also available for mobile devices and HMDs. Even though the average consumer doesn't have access to HMDs the use of these devices is being normalized in the manufacturing and quasi-manufacturing settings as a maintenance tool [50]. However, in this industry it is also used to help technicians with repairs and assembly.

6.5.1 Range Rover Re'flekt solution

Range Rover AR solution [51] aims to reduce costs and risks of complex repairs. With an iPad the technicians have access to all the necessary repair steps as they point the camera towards the engine.

The main benefits of this solution are:

- Fewer mistakes in complex tasks with reliable, easy to understand repair instructions;
- Quick access to all consolidated information in one place, every single time;
- Reduced training costs through more efficient training and fast learning.

6.5.2 BMW Augmented Reality Car Repair

BMW uses TSARAVision Smart Glasses in their workshops in order to facilitate the repair process through collaborative work with engineers and other experts. [45]

In 2009 BMW created a prototype of smart glasses that help identify engine problems.

> " The idea is that by wearing these glasses, you will be able to glance over a BMW engine, and parts of it will be highlighted in different colours, allowing you to spot common mechanical problems." [38]

Yet there's not a lot of information of recent developments or creations by BMW for that type of glasses.

6.5.3 Hyundai Virtual Guide

The Hyundai Virtual Guide is the brand's take on the traditional owner's manual that allows consumers to use their mobile devices to get information on vehicle features and on how to perform repairs and maintenance.

> "Hyundai used quality consumer survey results to determine the top difficult-to-use features to incorporate into the Virtual Guide. The app also contains 82 how-to videos, six 3D overlay images that appear once users scan areas of their vehicle like the engine bay and more than 50 informational guides." [36]

6.6 Conclusion

In conclusion, augmented reality technology is already being used with success in this industry, however, since it allows for many different solutions, it is important to evaluate them and gather the users feedback and expectations. It is paramount to study the preferences for these kinds of experiences, for example, for marketing and sales, should they be reserved to the dealership or integrated with the marketing experience as a mobile ad, in order to understand which choices bring more value to the client.

Chapter 7

Methodology

A design thinking approach, defined in the section 2.2.1, was chosen as the methodology for the development of this dissertation. It allows for the integration of the user throughout the process and provides the necessary flexibility to changes that may happen during the study.

This study doesn't just concentrate in usability and interaction of Augmented Reality but also in bringing value to the costumer through marketing and service science. As so, the methodology used will also take into account marketing research techniques.

The problem this dissertation tries to answer, as mentioned in the chapter 1, is if Augmented Reality can provide reliable solutions to the automotive retail industry, and in particular, marketing and sales. This is done by studying in depth the current process through identification of its weaknesses and strengths, analyzing current applications of this technology in the industry, and by designing and evaluating prototypes.

7.1 Design thinking approach

In the figure 7.1 is represented the design thinking approach that is used in the study of our problem. By understanding the user needs involved and reexamining the problem in each iteration, it is possible to explore different ideas and take a hands-on approach through prototyping. This approach was also chosen because it is a non-linear process that allows for more flexible solutions as the study is being developed.

"The first stage of the Design Thinking process is to gain an empathic understanding of the problem you are trying to solve" [21], in this case understand how users perceive AR experiences and the current automotive retail experience.

In the second stage of this process, it is analysed the observations and information. Next, those are synthesised in order to define the core problems in a human-centered manner.

The third stage is the *Ideate* stage, it is the brainstorming moment, that generates possible solutions to the problem defined in the second stage of this process.

The prototyping phase, through the production of various levels of fidelity tests investigates the possible solutions identified in the Ideate stage.

The last stage is testing those prototypes with users and evaluate them, in order to gather valuable feedback from users, and possibly identify problems before they appear. At the end of this phase we are able to reformulate one or more problems and update the understanding of the users, the settings of use, how people think, behave and feel, and to empathise.

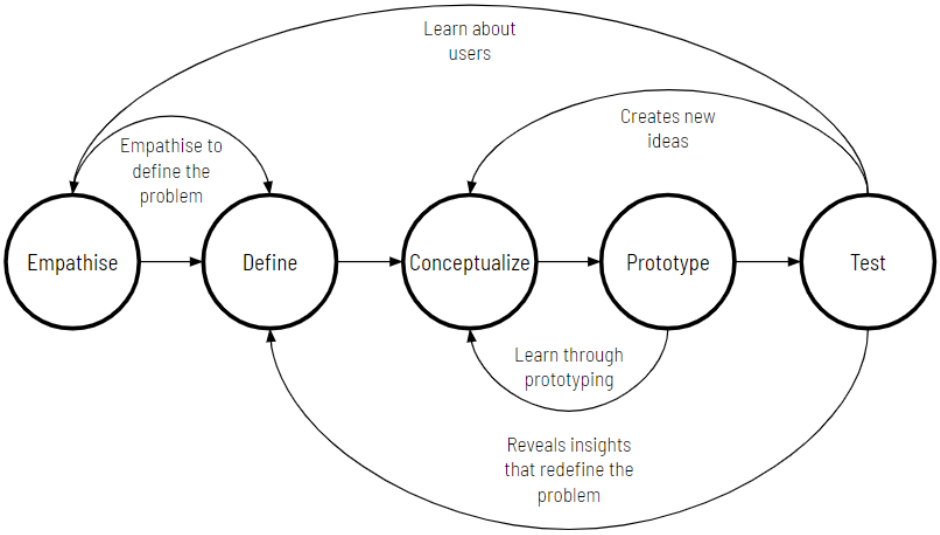


Figure 7.1: Design Thinking Process

At the end, we aim to have enough evidence to support our claim that Augmented Reality can bring valuable experiences to the automotive retail industry and allow meaningful engagement with clients, making it more consumer-centered and expand dealership experiences.

7.2 Marketing Research

In the chapter related to marketing, chapter 4, the key topics related to marketing research were described in 4.2.2. The marketing research process shares a lot of similarities with the design thinking process, however, it separates itself into three types of research: exploratory, descriptive and causal. In this project, a exploratory research was performed on the relationship and experience of customers with automotive retail, in addition to how they regard augmented reality and the applications available. This is done through surveys and tests made to existing AR applications. The data gathered by this exploration is then used to create a prototype, followed by user tests.

7.3 Construction of the research

In this section it will be explained how the research was constructed and the choices behind each instrument used to gather data.

7.3.1 Questionnaire

As a first approach to the topic of auto-retail and the use of Augmented Reality, a survey available in two languages was made, one in English and another in Portuguese.

The English version was made in order to obtain a more international perspective, however, the main means to publish it, mostly forums, didn't assure a diverse and large enough sample to gather relevant information from. For this reason and as a way to break the language barrier, it was also created a Portuguese version that would be easier to spread.

Both versions are available in the appendixes A and B.

The first section of the survey intended to gather the socio-demographic data of the population sample: gender, age group, occupation and if they owned a vehicle or not. The second section objective was to understand the costumer's relationship with the automotive retail industry, with a focus on the vehicle sales.

As an opening question we asked if they had been recently interested in buying or leasing a car. The aim of this question was to separate the sample into people that have researched vehicles and possibly contacted dealerships recently enough to have an opinion about it.

The second, third and fourth questions were related to the means of providing information, such as magazines or digital media like websites and applications, and the opinions about the accessibility and quality of the information in those channels.

In the following questions of this section it was evaluated the importance and satisfaction given to each step of the process of buying or leasing a car, as well as the value given to aspects of the purchase and the dealership visit.

The third section is dedicated to the opinions on the use of Augmented Reality in the industry. Since it is a technology often confused with virtual reality the definition and a link to a video example and images of already existing applications were included in order to avoid confusion when answering the questions. In this section it was asked if the three types of AR solutions currently used in the industry (product personalization, product visualization and experience, demonstration of vehicle characteristics and features - see chapter 6) could improve the buying experience, and if and under which circumstances would they use it.

The final section wasn't mandatory since it was directed at the people interested in participating in the testing and interviewing phases and asked for their contact information.

The objective of the questionnaire was to obtain a general impression of the problem and empathize with possible users and costumers.

7.3.2 User tests to existing AR applications

As a continuation of the questionnaire, user tests at three AR applications for automotive marketing and sale (already available to the public) were planned in order to better understand how users perceive them in terms of AR design but also the relevance of the content presented. Both the navigation and the information presented were to be analysed in order to gather opinions about the

AR interaction and the frustrations and perks associated with the different designs, but also what's most desirable content to be presented in an application for sales and marketing purposes.

Each participant tests one single application to guarantee an unbiased opinion, considering that most applications had different types of interaction and content. The goal was to understand the user behaviour and perception, and not their preferences.

Each test started with an explanation of the goals of the study, then the participant was asked to sign a consent form and the pre-test questions were made. The consent form is available in appendix E.

Pre-test questions:

- Were you interested in buying or renting a car recently?
- Have you ever used an application/website to gather information about a car?
- Have you ever used an AR application?

These questions help to better understand the knowledge, comfort and interest each tester has with each topic.

The moderation technique chosen for these tests was Concurrent Probing (CP), characterized by requiring that participants work on tasks and the researcher is allowed to ask follow-up questions of some of the decisions made by the testers while they are doing the tasks (see sub section 2.2.3.3). The test itself was composed of 6 to 9 tasks depending on the application being tested, see table 7.1, and at the end of each task some quantitative measures were assessed: error rate and successful completion, but also subjective metrics: satisfaction, ease of use, ease of finding the information and likes and dislikes.

The tasks consisted on:

Table 7.1: Tasks for each existing AR application

Tasks	**VW Nivus**	**VW Touareg**	**Porsche Visualizer**
Choosing the model/version	✓		✓
Positioning the vehicle, resize, rotate and move	✓	✓	✓
Changing the colour	✓	✓	✓
Changing the rims	✓		✓
Getting inside the car as if you were the driver	✓	✓	✓
Exploring the features and explanations	✓	✓	
Exploring accessories	✓	✓	
Exploring drivetrain/structure	✓	✓	✓
Opening the dealership/brand website	✓		✓

1. Choosing the model/version;
2. Positioning the vehicle, resize, rotate and move;
3. Changing the colour;
4. Changing rims;
5. Getting inside the car as if you were the driver;
6. Exploring the features and explanations;
7. Exploring accessories;
8. Exploring the drivetrain/structure;
9. Opening the dealership/brand website.

As mentioned previously, three applications were chosen: two experiences by Volkswagen, one for the VW Nivus [71] and the other for VW Touareg [40], and the AR visualizer by Porsche [53].

The VW Nivus application was chosen because it was available in portuguese which allowed the inclusion of non-English speakers in the study and had similar options in comparison with the other two applications (see figure 7.2).

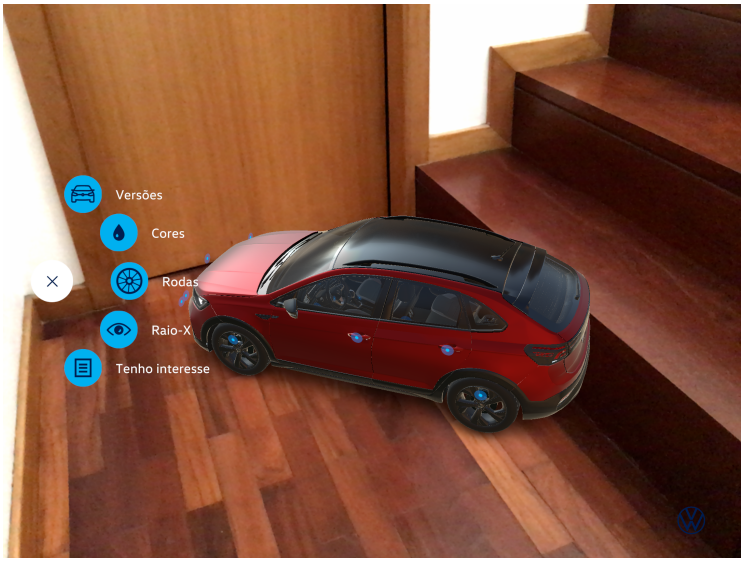


Figure 7.2: VW Nivus experience in Portuguese

The VW Touareg experience incorporated sound into the experience, making it a multimodal output system. While most applications were silent, this experience had a narrated explanation of the features and accessories of the vehicle (see figure 7.3).

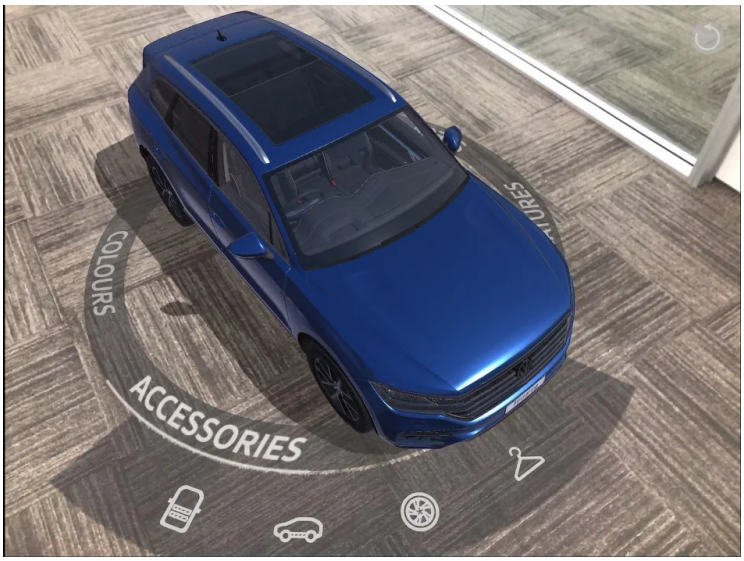


Figure 7.3: VW Touareg experience [40]

The Porsche application differed from the other options in terms of content: it had variety of models and the customization that was in AR could then be sent to the website where it was possible to save it and customize even further (see figure 7.4).

The first task (1) is for the Porsche test, due to the offering of different models and versions, but also at the VW Nivus application which provides three different versions of the model, and the offerings in terms of colour and rims changes according to the version that was chosen.

The tasks 2,3,4 and 6 are executable in all applications, some with more details and options than others. The fifth task, 5, was created in order to study how an user would explore the whole vehicle through AR, and not just the visible exterior. This is done to understand how much of the real experience of seeing a car can be brought into the AR experience.

The following tasks, 7,8 and 9 were planned considering the features of each app.

At the end of the test the following questions are asked:

- What did you think of the experience?
- Do you see yourself using this application? In what type of situation?
- Would you use a similar application when researching for a vehicle to buy?
- What do you think were the strongest points of the application? And the weakest?
- Is there any feature that was missing that could bring value to this type of applications?
- Do you think the availability of these types of applications would improve your relationship with the brand/dealership?
- How do you compare the experience with AR with the other traditional means of obtaining vehicle information? Dealerships, magazines and other applications without AR.

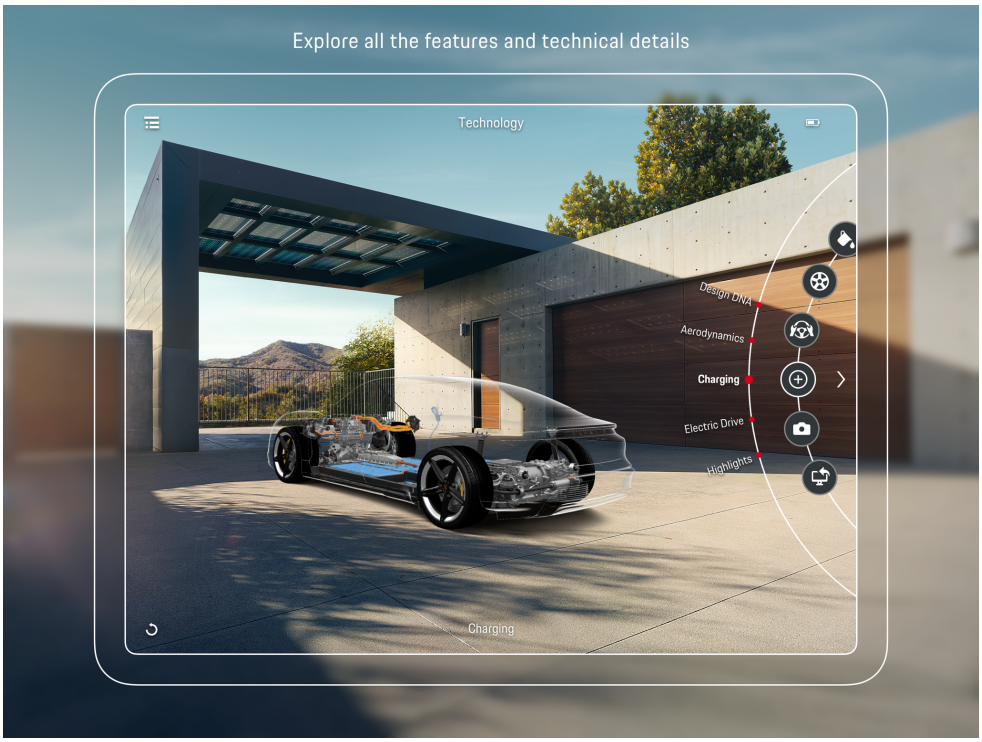


Figure 7.4: Porsche Visualizer [53]

7.3.3 Prototype Development

A prototype was created considering the information collected through the questionnaire and the user tests performed. It was developed taking into account the types of features and information an Augmented Reality application for the automotive retail sector so that could bring pleasant experiences and value to the costumer.

Due to the limitations of prototyping tools, in addition to restrictions in testing within a dealership context as a result of the Covid-19 pandemic, a prototype of a mobile application with similarities to the tested applications was chosen.

The prototype was made with the purpose of being a research tool to be used by interested consumers as an interactive surface introduction to the vehicles available from the dealership or brand. In contrast with the two VW applications tested, the prototype would have several vehicles to choose from.

The interviewed users often associated the information available in the tested applications as the type of information they seek at the beginning of their search for a vehicle. This search is more of a pre-selection, the exploration of a more visceral response to the cars, focusing on appearance, in particular, the visualization of the interior and exterior and some key features. In that moment of the search process it is important to also have a variety of models for their convenience.

The comparison with vehicle customization applications was often made, even though these had more options and information, they weren't as interactive. With that in mind, more technical

details were added than those present in the tested apps, in addition to the availability and price of the vehicle. The prices presented also had in count leasing options. This information allowed for more reflexive responses from the users and a feeling of increased transparency regarding prices and details. This is shown in figure 7.5

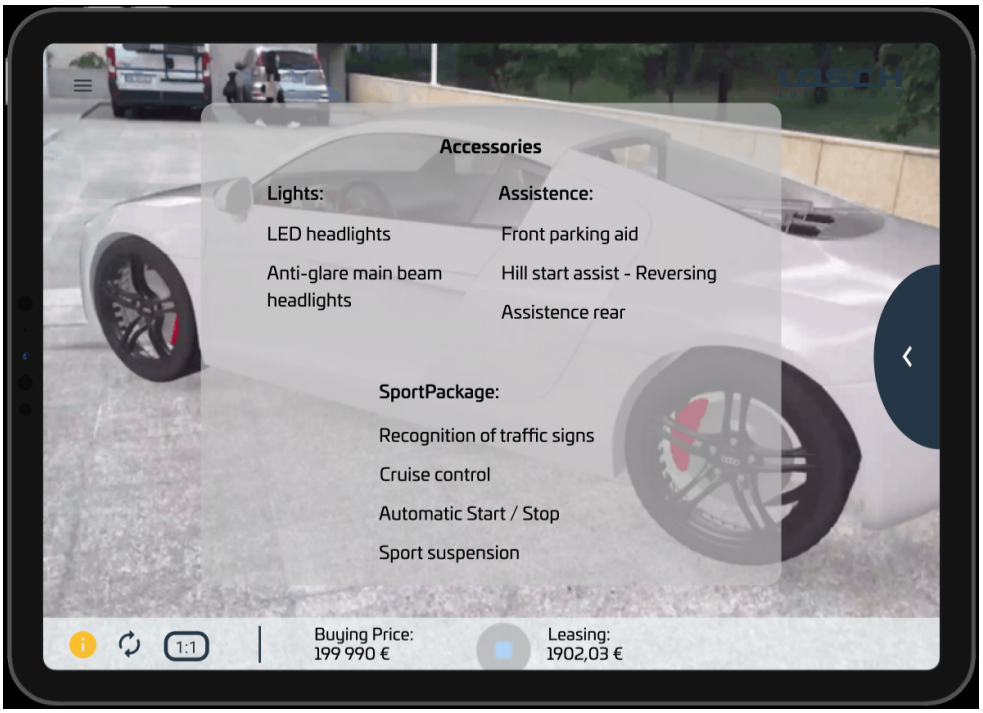


Figure 7.5: Accessories list screen for more valuable information

The explanation of some features was also very appreciated by the testers and the interactive visualization pleasantly surprised most. However, due to the difficulty in finding 3D models of the mechanical parts, this prototype was made with just visual explanations of a feature of driving assistance. However it wasn't very perceptive due to constraints in interaction with Reality Composer.

The major issue testers had was not knowing that they could explore the inside of the vehicle, for that reason some tips were added in the loading screen but also the inclusion of a yellow button with explanations on how to interact with the 3D model present in all screens. After the firsts tests were made, it was suggested that a menu option that reiterated the steps on how to explore the inside should be added. One of the loading screens is shown in the image 7.6.

Overall the prototype was composed by the following screens:

- Initial screens:
  - Homepage;
  - Search;

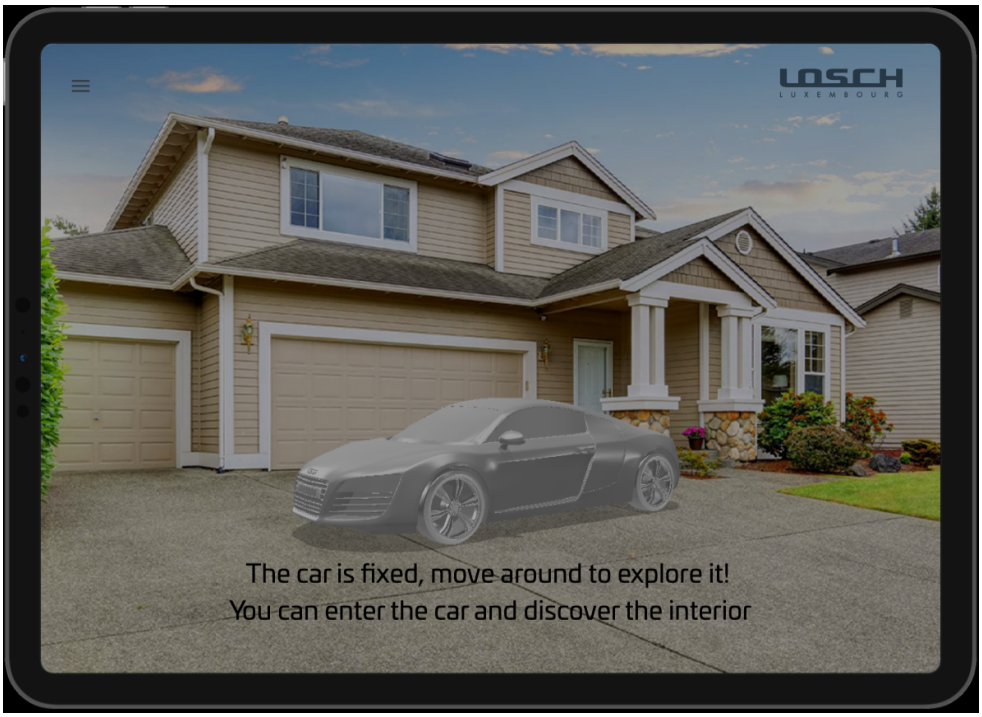


Figure 7.6: Loading Screen

  - List of vehicles;
  - Overview of a vehicle;

- Augmented Reality screens:
  - Loading screens with tips on how to deal with the AR environment: incentivize movement, how to place and change the object position;
  - The first visualization of the car;
  - Real size of the vehicle;
  - Exploration of the inside of the car;
  - Features screen, where due to the limitations of figma, the buttons that open the overlay needed to be fixed and for that reason it didn't make sense to add a video to the background. This also applies for the accessories list screen;
  - Accessories list;
  - Video example of a driving accessory explanation;
  - Rim options;
  - Colour options.

For the features screen the buttons chosen were all the same since it didn't trigger an action and just showed information, if those two types of interaction were present it would be important to create a distinction between those who triggered an action and those who showed information.

It also had present on the left side of the screen a menu that allowed the user to go back to the homepage, and on the right side a menu for the AR interactions, represented in figure 7.7.

Figure 7.7: AR menu

The overlays with information were intentionally small, especially those that were meant to help with the immersion or seen in simultaneous with the model, as for the size of the overlay with the list of accessories, it was made bigger because the information didn't need to be seen with the model, and the user's focus was completely on the text being displayed. Leaving the AR scene was a possibility but since the positioning and loading were the most frustrating moments of the experiences the bigger overlay was a good solution.

In order to obtain input from users during the development, low fidelity prototypes were initially created using Figma (a tool commonly used for web design) and static images of 3D scenes with the help of Adobe Dimension, but it was observed that it lacked the illusion of Augmented Reality and, for that reason, a more medium fidelity prototype was created with the use of video of the augmented scenes.

The first prototypes are available in the following link: `https://www.figma.com/file/u9IlI38TDJ6Y2nZ0BsPtWj/Thesis_prototype_first`

As a first approach to the video solution, it was planned that it would be used the Torch app since it allowed for a simple integration with Figma, however, during the development of this dissertation it was announced the termination of that tool. Considering this, it was used Reality Composer that, even though it didn't create links that could be called in Figma, it still allowed for triggering behaviours and the creation of different scenes.

Figure 7.8: First static prototype (low fidelity)

As for the 3D model used, it was free to use and was made available in the platform TurboSquid. The 3D model of the Audi R8 used is the one in the reference [65].

One of the challenges of the development of these prototypes was dealing with the 3D models and the different formats available. Most weren't compatible with the prototype applications chosen, others weren't flexible enough to change details such as the painting and rims, also, initially the file size was too large for AR, and had to be reduced. These changes were made using Cinema4D tool. As mentioned, Reality Composer only supported the USDZ file format, and Torch allowed for OBJ and FBX formats, so, when the change between applications was made, the model's conversion had to be made through the use of USDPython.

The videos were recorded using the screen recording tool of the iPad and for editing purposes Adobe Photoshop 2020. These videos had to be saved as GIFs since Figma only supports that type of file.

This last version of the prototype is available in https://www.figma.com/file/Vv6yqKYdJWDptXkJU
Thesis_prototype_videos

7.3.4 Prototype Testing

The prototype was evaluated throughout its development, by asking users which were the features they valued the most and how could they be improved, as well as getting validation of those already implemented.

At the end of some iterations tests made in similar conditions to the ones made with the existing applications were carried out. Yet, for this test a Concurrent Think Aloud (CTA) as moderation technique was chosen (see sub section 2.2.3.3). These tests were made focusing in the utility and not as much in the effectiveness of use since it was a medium fidelity prototype, however, some design decisions were evaluated.

After signing a consent form, users were allowed to explore and interact with the prototype while thinking aloud, and at the end the following questions were asked:

- How did you feel using the application?
- Do you see yourself using a similar application? In what type of situation?
- Do you feel that the visualization of the vehicle and the information was seamless?
- What do you think were the strongest points of the application? And the weakest?
- Do you see this AR experience as a way to substitute the traditional experience or as an added content?
- Is there any other feature that you think could bring value to this type of application?

The consent form is available in the appendix E.

7.3.5 Limitations

There were two major limitations in the development of this dissertation:

The first being the quarantine and gathering restraints due to the Covid-19 pandemic that postponed the user tests and made focus groups impossible as a means of gathering data. In addition, this made testing applications or prototypes in the context of a dealership impossible.

The second limitation was the overall lack of AR prototyping tools for the design of applications with stick on screen menus. This made the prototyping development harder since three different tools (Reality Composer, Figma and Adobe Photoshop 2020) were needed to create the illusion of interaction. It also didn't allow for the creation of higher fidelity prototypes that could bring the AR experience to the test participant's surroundings by accessing the camera and overlapping the captured image with the 3D model or at least GIFs with transparent background for example.

There was also limitations on the 3D models available, that in perfect conditions, should be AR ready and animated, for example, doors that could open. It should also bring the mechanical structure in order to show those details.

Yet, considering all those limitations, the gathering of data and the prototype development and testing just took longer than planned initially, but were still able to bring valuable information regarding the context of this dissertation.

Chapter 8

Data Analysis

This chapter presents an analysis of the data that was collected throughout the development of this dissertation with the objective of exploring the use of Augmented Reality as a sales and marketing tool in the automotive retail industry.

8.1 Exploratory Results

Both the surveys and the user tests of existing AR applications served as a first contact in understanding of user's impressions, expectations and interactions with the automotive retail industry, augmented reality and its applications within the industry.

8.1.1 Survey's results

The goal of the surveys was not to do a statistical analysis, instead, they are an exploration of the context in which this dissertation is developed upon. For this reason the sample size is not large enough to have statistical value and the relation between questions will not be considered in this analysis. Alternatively, we will focus on a broader interpretation of the results.

The sample was of overall 250 participants, 143 in the Portuguese version and 107 in the English version. In terms of age there was a balance between the age ranges, and regarding occupation, most were employed. The majority of the participants owned a vehicle, but only half had been interested in buying or leasing a vehicle recently.

In relation to access to information about vehicles, most use digital media like websites and applications, considering the information available of easy access and good quality.

Concerning the understanding of technical specifications, a higher number of participants said that they were easy to understand (marking 4 in a scale of 1 to 5), yet a substantial part of them did feel as if they were somewhat difficult to understand (marking 2 or 3 in a scale of 1 to 5).

The steps for buying a car with higher importance were the research (information such as features and prices) and car experience (test-drives for example), while the visit to the dealership

was the third most important. As for satisfaction with each step, most participants were satisfied with the steps with higher importance and were mostly indifferent to the less important ones: preparing documents, car customization and delivery time.

Even though they didn't value the customization of the car as a step in the buying process, the number of participants that value customization during the purchase was considerable, however, seller support and variety of options were more valuable.

As for the dealership experience, most were satisfied with it, having more interest in test-drives, contact with the dealer, variety of vehicles and explanations of technical characteristics.

Concluding this section, the participants were mostly satisfied with the auto retail industry in general and the car buying process.

As for the augmented reality section, more than half of the participants said they never used an AR application before or they weren't sure. This reflects on the misunderstanding and lack of awareness of the technology, since one very known application of this technology is filters in photos and videos popularized by Instagram and Facebook.

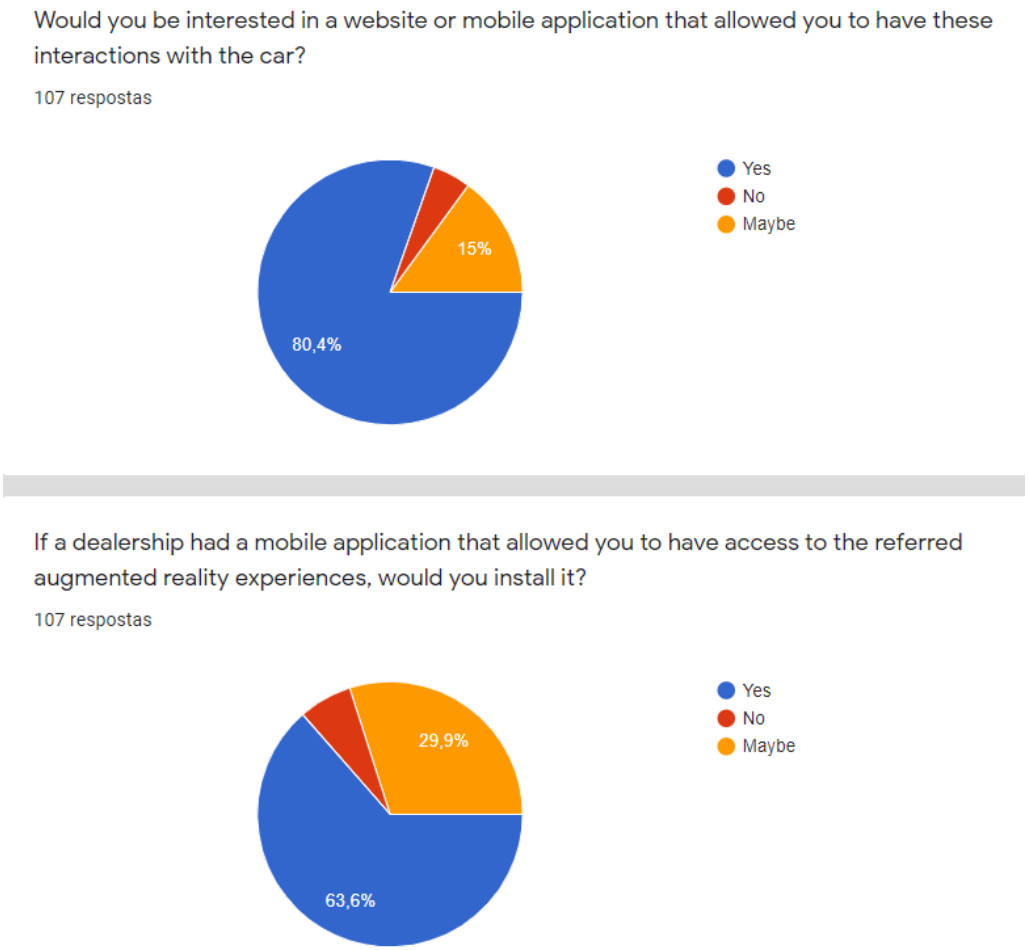


Figure 8.1: Answers regarding interest for AR apps for auto sales in the English survey

The application of AR that they considered with higher potential to improve their experience while buying a car was the car visualization. This was later confirmed in the tests where, even though users were amused by the customization possibilities, the details and realism of the model presented were more relevant to the user. In line with that, the use of these AR applications wasn't restricted to the dealership, and there was an interest in using it both at home and in the showroom. A great interest in applications of this kind was manifested, as shown in the figure 8.1.

The entirety of the results is present in the appendixes C and D.

8.1.2 Results of user tests to existing AR applications

The user tests were conducted with three participants for each application, in total nine participants were present for these tests.

As previously mentioned, three questions were asked before each test:

1. Were you interested in buying or renting a car recently?
   Most users had been recently interested in buying a car, having been through the research process at least.

2. Have you ever used an application/website to gather information about a car?
   The participants had used such applications, especially to check prices and to customize the vehicle as part of a first research.

3. Have you ever used an AR application?
   Even though not completely in line with the results of the survey, half of the participants said they had already used an AR application, however, it is important to refer that those participants had contact with it through video games.

The videos of the usability tests performed are available in a YouTube playlist in the link: https://www.youtube.com/playlist?list=PL27hjTmsX0fvkvn6VZcq6eeS3zlTradDR

For the Porsche tests, the application was shown to have a technical issue with surface detection. In all of the tests users had difficulties with object placement. Other technical problems were the disappearance of the side menu and lagging when seeing the motor.

The change of colour and rims was always easy, however, users questioned the accuracy of the colours, which noted a concern for realism and detail.

The fourth task, where it was asked to open the back of the car, was faced with some drawbacks, mainly due to a poor explanation of the task to the users. The menu was criticized mostly regarding the "Technology" tab since the icon chosen (a plus sign) didn't convey a clear message regarding the action that it triggered.

The exploration of the interior was the task that faced more struggle throughout all three applications, all users needed a tip on how to explore it. It was observed that until that task most participants didn't move a lot but opted to rotate the vehicle in order to see it from all perspectives.

This was mainly due to a lack of conviction that the car was sticking to a place in the real world. This wouldn't be an issue with marker based AR or with incentives to move during the experience.

The simulation of contacting the dealership/brand was well received seeing that it confirmed the intention of leaving the application and opened the website with the customization made in the experience, while also giving more options of personalization and prices.

Regarding the VW Nivus experience, it didn't have the same issues as the Porsche application with surface detection, however, in some instances, the model would slide away from the screen unprompted.

The major complaints and hardships were mostly due to language, since it is a Brazilian application some words are not very common in european portuguese which caused some confusion, more specifically, regarding rims and versions.

As for the features, the popular opinion is that the navigation (the small blue dots always visible in the vehicle) was hard, either by not being very visible or by some triggering an action, like opening the door, while others presented information. Nonetheless, the information presented in the features was detailed and satisfactory. Yet the mechanic parts received criticism for lacking detail and overall having insufficient information.

The VW Touareg experience was different than the other two applications due to sound being incorporated into the entire experience. As for the effects of that, users complained about the music being constantly playing, but appreciated the narration. Even though the information presented wasn't more complete than the other applications, no user complained about a lack of detail. This could be the result of the combination of the written text and the narration that improved the comprehension of the information. In spite of that, the navigation was critiqued:

- The menu would change places when the user got closer or farther away from the vehicle, causing confusion.
- The rotation of it wasn't perceptive.
- Lack of feedback when selecting accessories.
- Icons not being descriptive enough.

However, the demonstrations of features were appreciated.

Overall, users said they liked the experience and that AR was more engaging than the customization and vehicle information websites. As said in the chapter 7.3.2, some follow up questions were also made. These questions focused on how they felt after the experience and their opinion on how these types of experiences could bring value to the industry.

Even though they liked the experience, there was always the need to mention that it didn't replace test driving and that was essential to the decision to buy a vehicle. For most, it served

as a research tool in, what was called, a "pre-selection", and that it should have several models available, much like the Porsche application.

One of the users presented a three step research that was validated in the following tests:

1. General, or the mentioned "pre-selection", more focused on the look of the cars. This is the step where they saw more value in the use of AR;

2. Characteristic based, where it would check the prices and some features that were important;

3. Detailed, where they would check the details of the vehicle considering their individual consumer needs, for example the fuel consumption. Often it was a more narrowed selection.

In the "pre-selection" phase most mentioned some discomfort with going to the showroom to do the research and being bothered by the dealer trying to pressure them into a decision. Yet, users still wanted to see the vehicle as a whole and not just pictures, and AR filled that need. However, the AR experience was also considered a good addition to the dealership experience, mostly because it is impossible for a showroom to have all the options available in terms of customization and that these options could be shown to buyers through AR.

An issue brought to the attention in many of the tests was that these applications didn't give the illusion of the real size of the vehicle and that in some cases it felt like a car toy, even though the 3D model was detailed. On one hand they wish for the availability of a more realist experience, on the other hand, the "portability" of the experience (being able to show the car anywhere due to the possibility to scale the model) was a strength of these applications. It was suggested that it should include a button to switch to a more realistic experience with attention to the real size of the vehicle.

In comparison with websites and magazines with vehicle information, AR is seen as a complement to them and not a replacement, mainly due to the lack of information, details and prices, but also, in the case of websites, by allowing comparison between vehicles specifications.

Regarding how the availability of AR applications by a dealership or brand would influence their opinion on said dealership/brand, the majority of users say that even though it wouldn't directly influence their purchase decision, it would give a good image to the brand in general since it would show that they are investing in new technology and in bringing the best possible experience for their customers.

8.2 Prototype Testing Results

As mentioned in the development of the prototype, see 7.3.3, the prototype was tested throughout its development, overall it was tested by six different users, however, just the three last tests were video recorded. Those videos can be found in the following playlist: https://www.youtube.com/playlist?list=PL27hjTmsX0fs3HAe_eD4rW1ORpIHTWo8z

The first tests were made with the static version of the application and due to being informal were not recorded. The main focus of those tests was to get opinions on features and find the best

way to display some of the information. It was during those tests that it was concluded that video was indeed necessary in order to obtain relevant feedback towards the use of AR.

The tests recorded were done with the last version of the prototype, and were met with some difficulties at the start due to the prolonged loading time of the videos that were running in the background of most screens. The tool used to show the prototypes was Figma Mirror for iOS.

One of the participants had already tried some AR applications for vehicle visualization and commented on how most didn't have the prices and that was a good and valuable addition. The icons chosen were not the best since it is hard to find an icon for features, accessories and also the exploration of the interior. Considering this, it was suggested that text should be used in the menus.

Regarding the post-test questions, participants said that they were excited with the possibilities that a similar application to the prototype could bring, and that they would use it. In contrast with the tests done to the existing applications, due to having prices, details, features and accessories all in the same place, users said they would use it for a more detailed research, and not just for visualization purposes.

As for how seamless the experience was, all participants said that the use of overlays felt natural and didn't break the immersion of the experience.

The strongest point of the application was, just like in the other tests performed, the visualization of the vehicle, and the weakest was few customization options, especially in comparison with the research websites without AR.

The participants considered that the prototype was very similar the web applications without AR available in terms of what was offered, but had an added layer of interaction and better visualization. As so, they ended up considering AR a good addition to that experience, but not as a substitute, since those applications also had comparison tools and for faster and detail-oriented researches were more convenient.

Something that was mentioned in these tests was that it would be important for the participants to be able to create a code with the customization and, when at the dealership, that code could serve as a reference to the seller.

8.3 Conclusion

As stated previously, the survey and user tests to existing AR applications served as an exploration of the context of sales and marketing in the industry. Overall, users are satisfied with the current, and more traditional, offerings of vehicle information, yet, it is considered that AR technology could improve those research tools.

The applications tested mainly focused on obtaining a visceral response from the users, more specifically, regarding appearance.

The prototype was developed considering some of the major hassles identified: showing prices and more details, having a variety of models and showing incentives to move and explore the

vehicle. The prototype tests showed a shift in the response from the users that had not only a visceral response but also a reflexive one. This is due to the new information added.

Nonetheless, in comparison to the applications without AR, the prototype still didn't fully replace them for two main reasons: the comparison tool and convenience in detail-oriented researches.

The vehicle comparison tool was overlooked during the prototype development, regretfully, since as suggested by a participant, it could be interesting to see two or more vehicles in the same AR experience. However, the tools used to make the prototypes didn't have the capability to support two vehicle models in the same screen, since the car model was very detailed and heavy, making the processing of it slow.

The major customer's benefits identified were:

- a more convenient complete visualization of the vehicle;
- reduction of unnecessary contact with dealers;
- providing interactive and easier to understand explanations of features and accessories;
- a more engaging customization process at the dealership.

Overall, Augmented Reality brought engaging experiences to the users and improved their perceived brand/dealership image, it showed that they were innovative and were searching for ways to improve the customer experience.

As for benefits for the dealership or brand:

- a better image (investment in technology and innovation as well as customer-centered);
- less futile and negative direct customer contact;
- less necessity of a big variety of vehicles in the showroom.

As mentioned previously, it is important that the choices made in the prototype application can be easily communicated to the dealers, creating a more connected channel strategy and becoming more convenient to the customers.

Chapter 9

Discussion and Conclusion

The goal of this thesis was to study and evaluate Augmented Reality as a tool to bring valuable experiences for the automotive retail industry.

In order to understand the context of this study concepts of interaction (see chapter 2) were explored, along with augmented reality (see chapter 3), service science and marketing (see chapter 4) , but also the current environment in which the automotive retail industry is placed (see chapter 5).

After the research mentioned, it was decided that it would be beneficial to narrow the study to sales and marketing and to mobile AR applications. These decisions were made due to Augmented Reality being a very wide-ranging term and the automotive retail industry having vastly different departments with different degrees of customer contact.

With those decisions and research in mind, a survey was designed (see sub-section 7.3.1) and tests were performed to existing applications in this market (see sub-section 7.3.2), which served as an exploratory marketing research. Later, a prototype was created (see sub-section 7.3.3) and evaluated (see sub-section 7.3.4), the results can be found in the chapter 8. In summary, it was concluded that AR did deliver valuable experiences to the customer, mostly by providing a tool that allowed for a full visualization of the vehicle in a more convenient way, and that those experiences could also bring positive outcomes to the dealerships.

However, the creation of the prototype was faced with a number of set backs due to the lack of flexible and easy to use tools for prototyping AR. This prevents the creation of high fidelity prototypes that can be used to better explore the users expectations and needs. It is also important to note that the majority of the prototyping tools that were explored were for mobile applications of AR, one of the most common types of AR display, and were still incomplete. Considering the existence of all the other types of AR display and the different types of interaction that can be associated with their use, better prototyping tools should be created in order to bring better user experiences.

In conclusion, AR can bring many different solutions to the automotive retail industry. In particular, for sales and marketing, it is able to create engaging and convenient mobile applications of vehicle visualization, customization and understanding.

9.1 Future Work

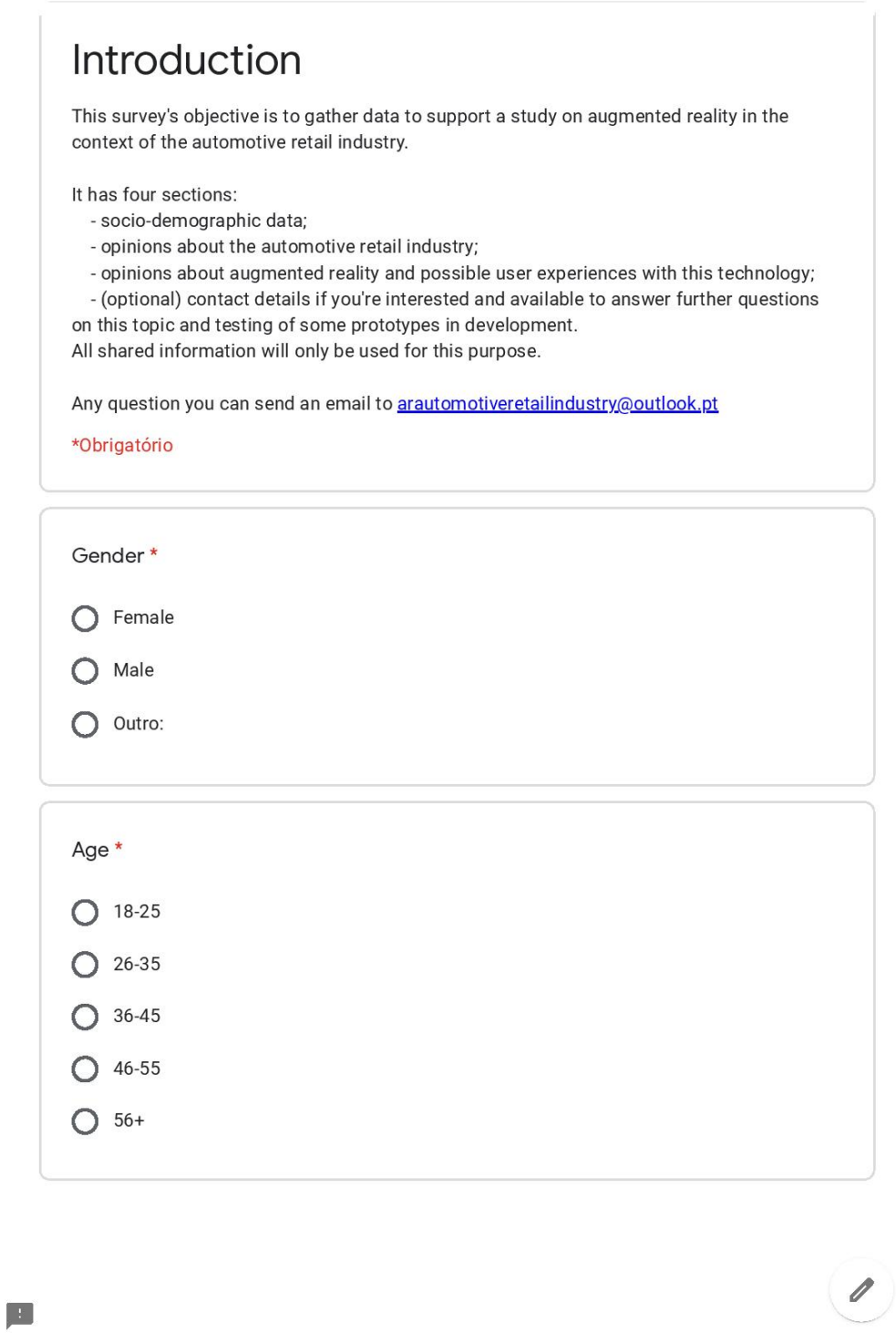
In the future it could be interesting to do a causal research on Augmented Reality and the correlation between the use of this technology and a possible growth in sales or costumer satisfaction, through the implementation of some of the options suggested in this thesis, whether it be displays at the dealership or mobile applications.

It is also important to remind that the automotive retail industry is not just vehicle sales, it is also connected to garages, whether it be for maintenance or customization. Considering this, it would be beneficial to study the applications of Augmented Reality as a tool for those areas of the industry, since there are other challenges present besides sales, that can be simplified by the use of Augmented Reality technology, such as inventory management and guidance through mechanical procedures.

During the study of Augmented Reality, see chapter 3, it was concluded that the term AR can cover a vast amount of technologies and interactions. This study focused more on mobile technology, yet there's still a multitude of AR solutions that can be explored as tools for the automotive retail industry. For example, what Audi City, see chapter 6, offers: auditory and visual experiences in a new type of dealership without vehicles.

Appendix A

English Survey



Introduction

This survey's objective is to gather data to support a study on augmented reality in the context of the automotive retail industry.

It has four sections:
- socio-demographic data;
- opinions about the automotive retail industry;
- opinions about augmented reality and possible user experiences with this technology;
- (optional) contact details if you're interested and available to answer further questions on this topic and testing of some prototypes in development.

All shared information will only be used for this purpose.

Any question you can send an email to arautomotiveretailindustry@outlook.pt

*Obrigatório

Gender *

- Female
- Male
- Outro:

Age *

- 18-25
- 26-35
- 36-45
- 46-55
- 56+

Figure A.1: English Survey - Introduction (part one)

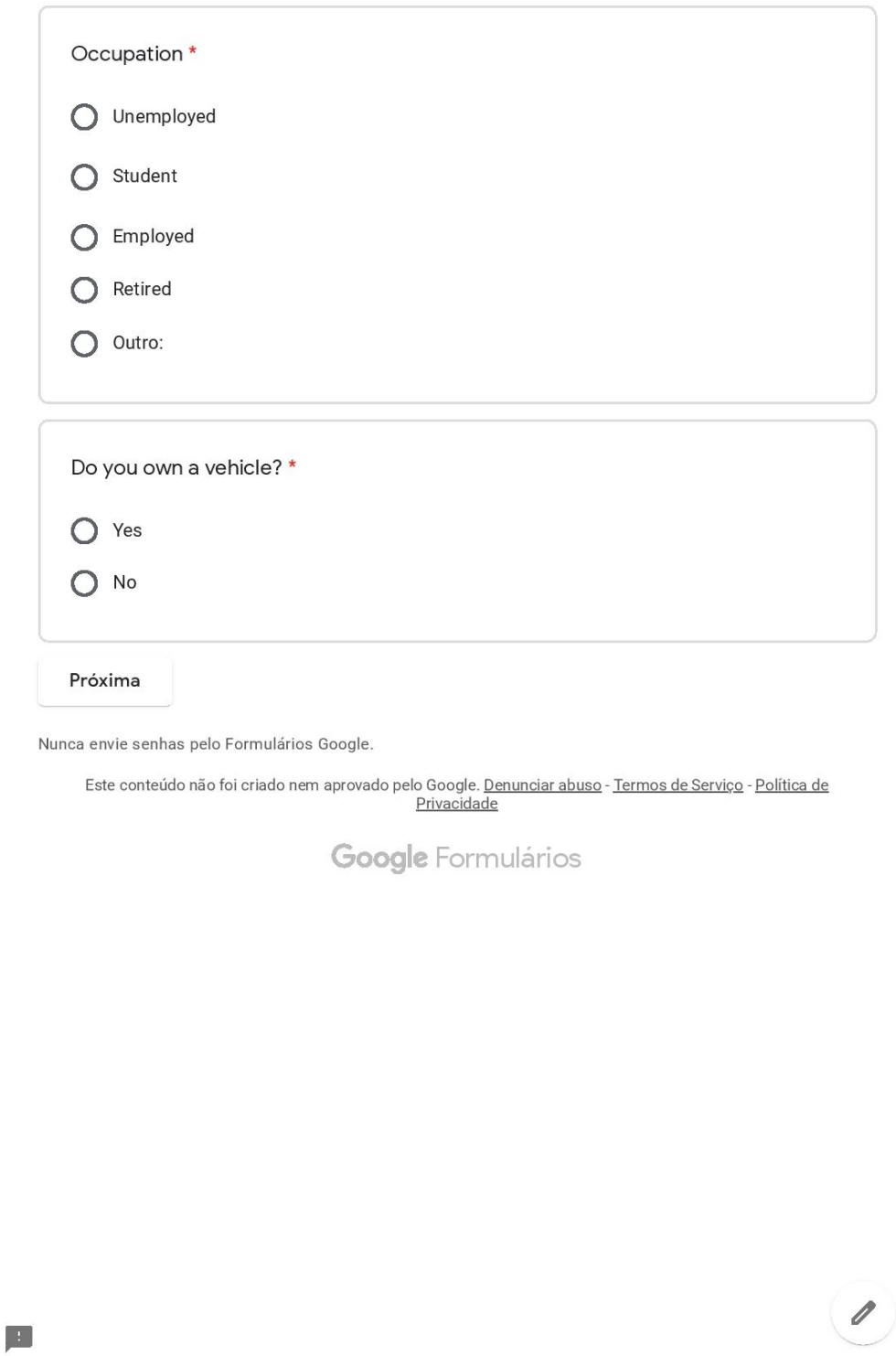


Figure A.2: English Survey - Introduction (part two)

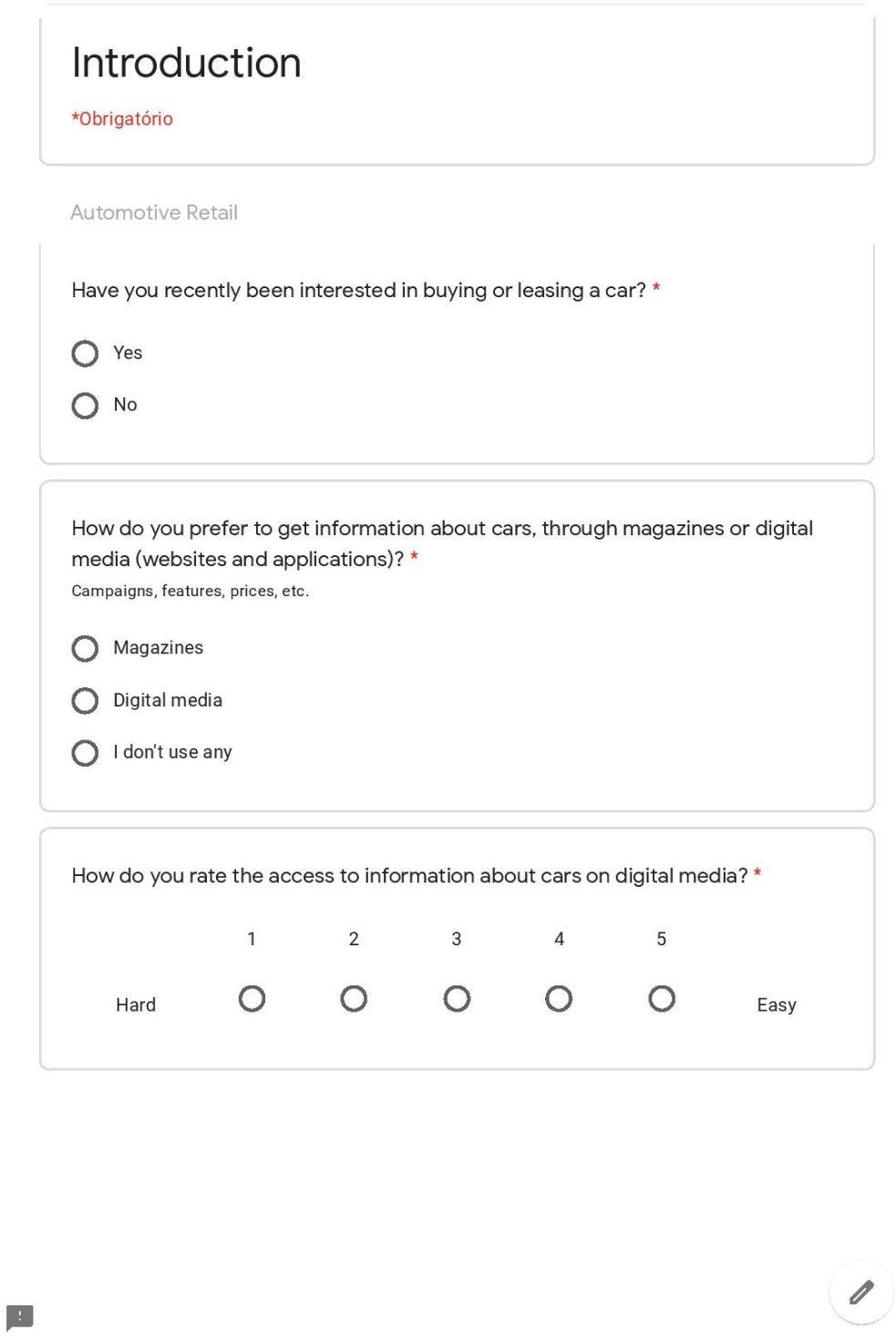


Figure A.3: English Survey - Auto-Retail (part one)

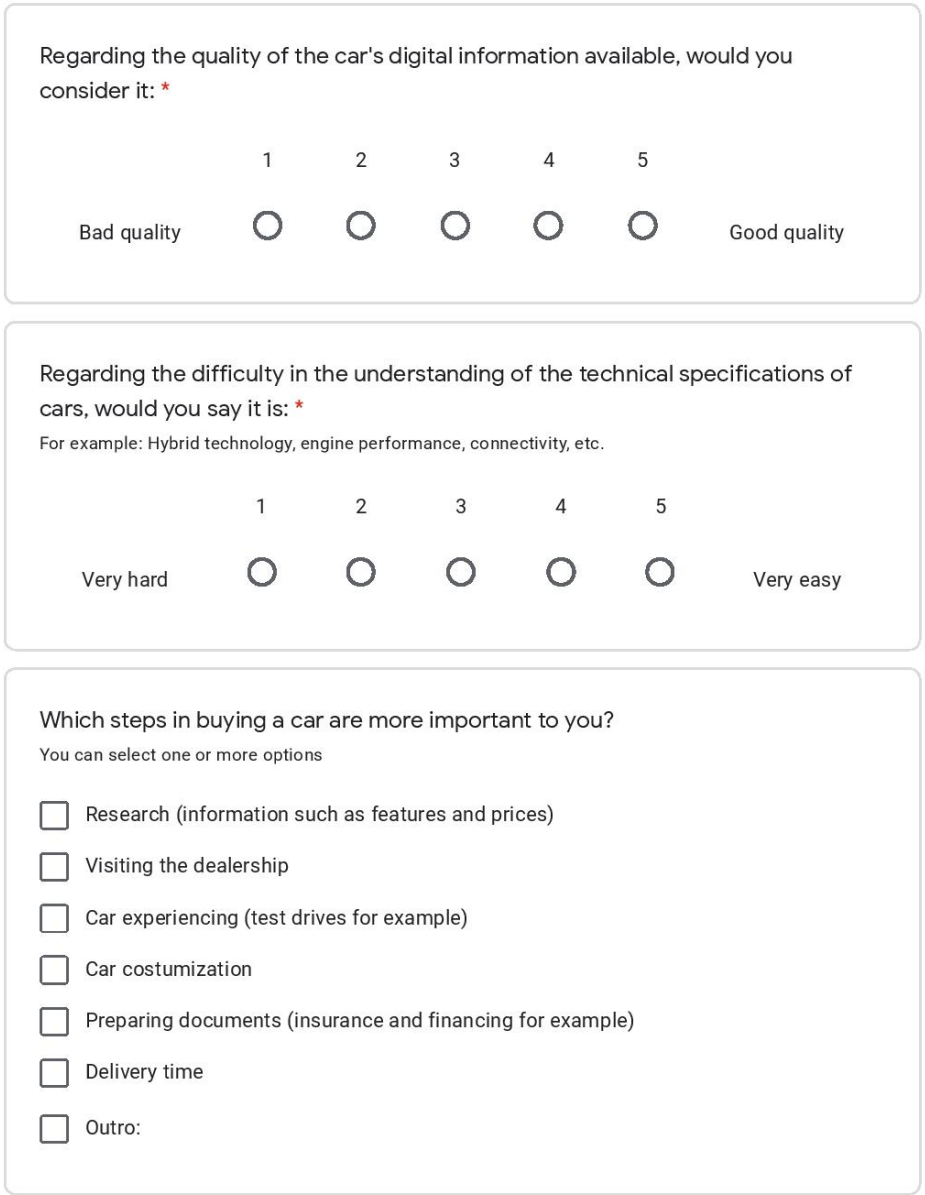


Figure A.4: English Survey - Auto-Retail (part two)

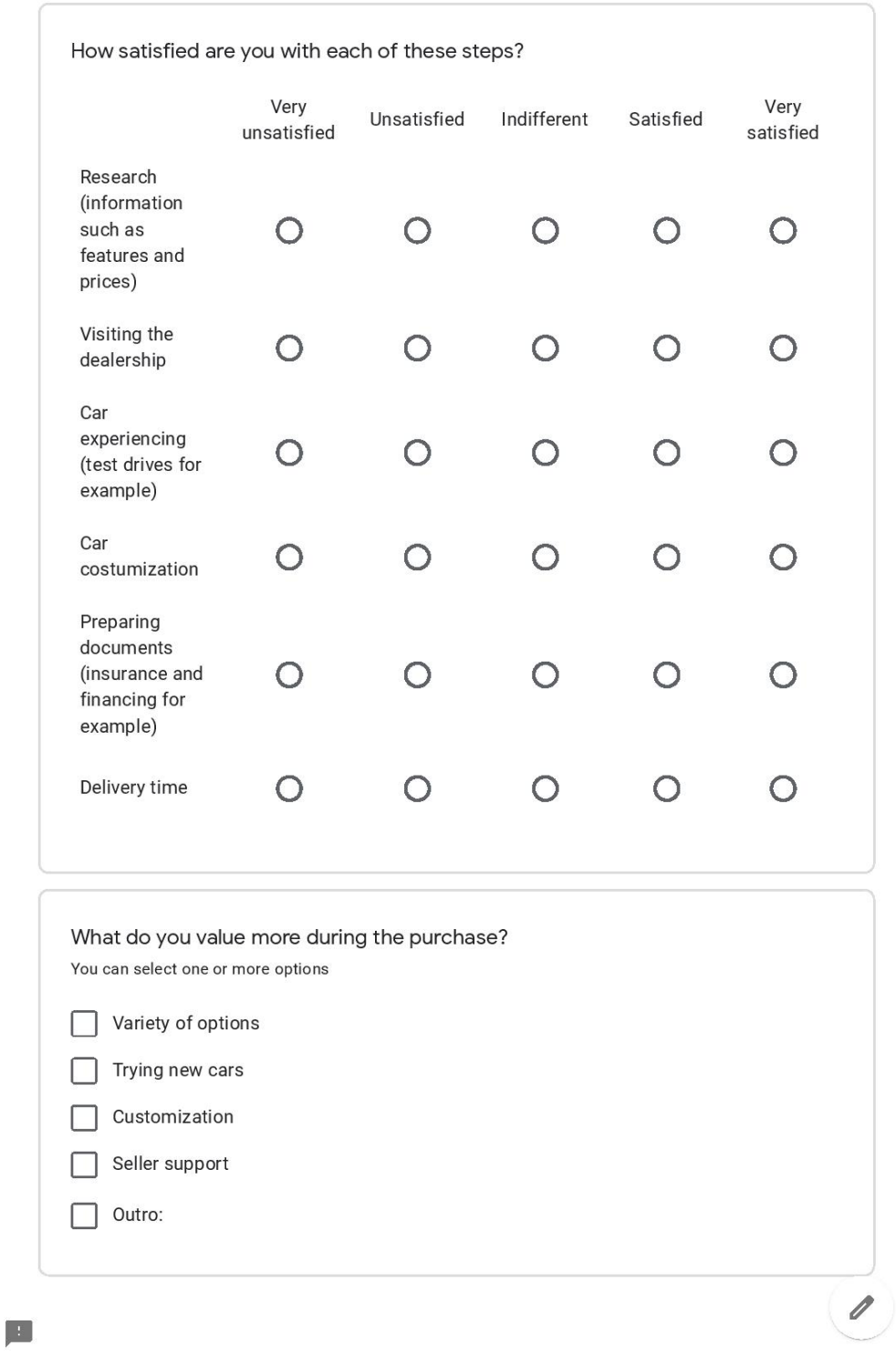


Figure A.5: English Survey - Auto-Retail (part three)

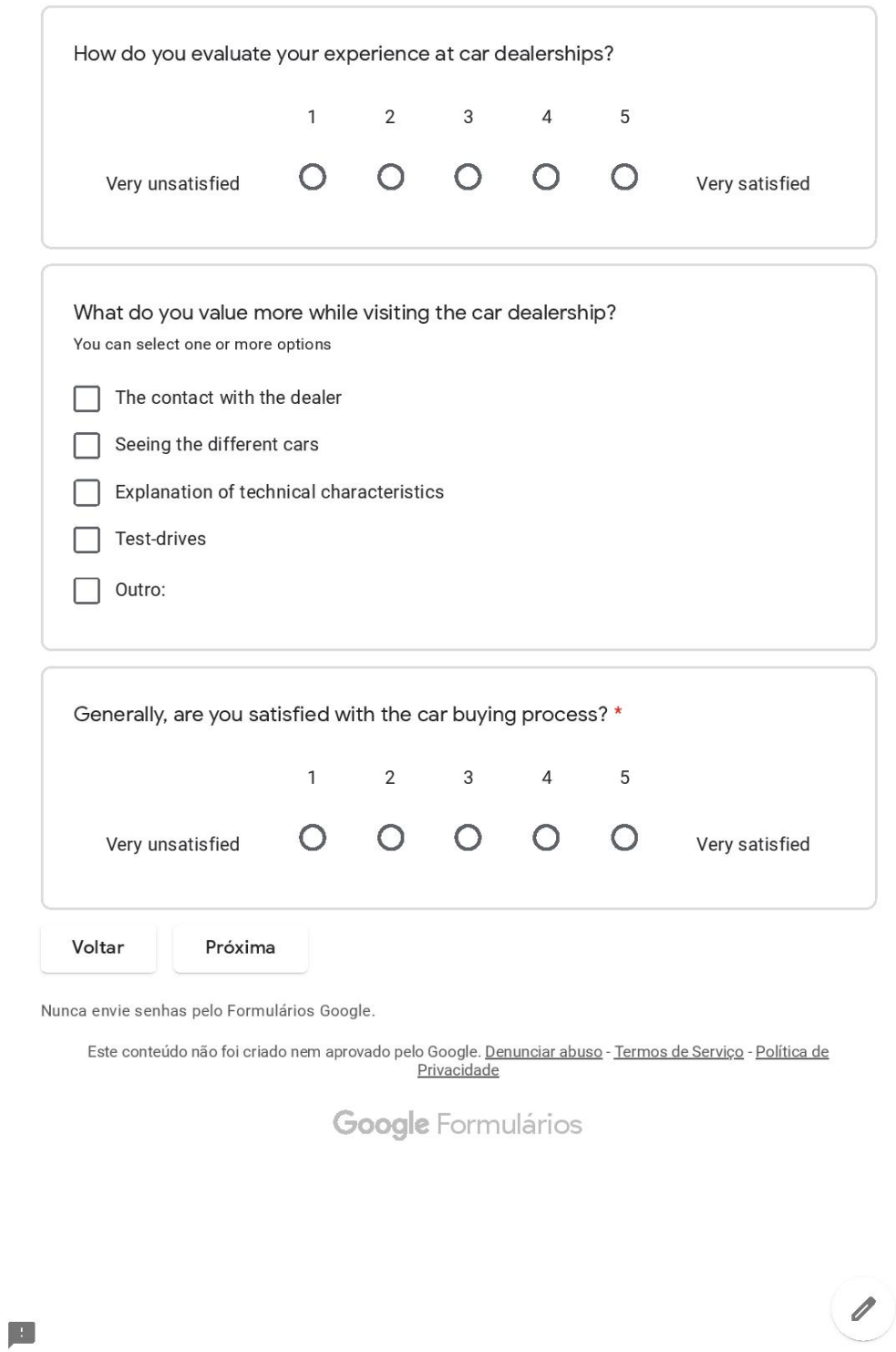


Figure A.6: English Survey - Auto-Retail (part four)

Introduction

*Obrigatório

Augmented reality

Augmented reality is a technology that allows, in real-time, adding a digital component to the perception of reality.

A video example:
https://www.youtube.com/watch?v=nTbSfyTbig8

The objective of this section is to understand how this technology can be integrated into automotive retail as a way to improve the customer experience inside and outside of the dealership.

Example of augmented reality

Figure A.7: English Survey - Augmented Reality (part one)

Have you tried any augmented reality applications? *

- Yes
- No
- Not sure

Select which augmented reality applications can improve the car buying experience: *

You can select one or more options

- Car visualization (exterior and interior)

- Interactive demonstration of the car's technical characteristics
- Outro:

- Customization

Figure A.8: English Survey - Augmented Reality (part two)

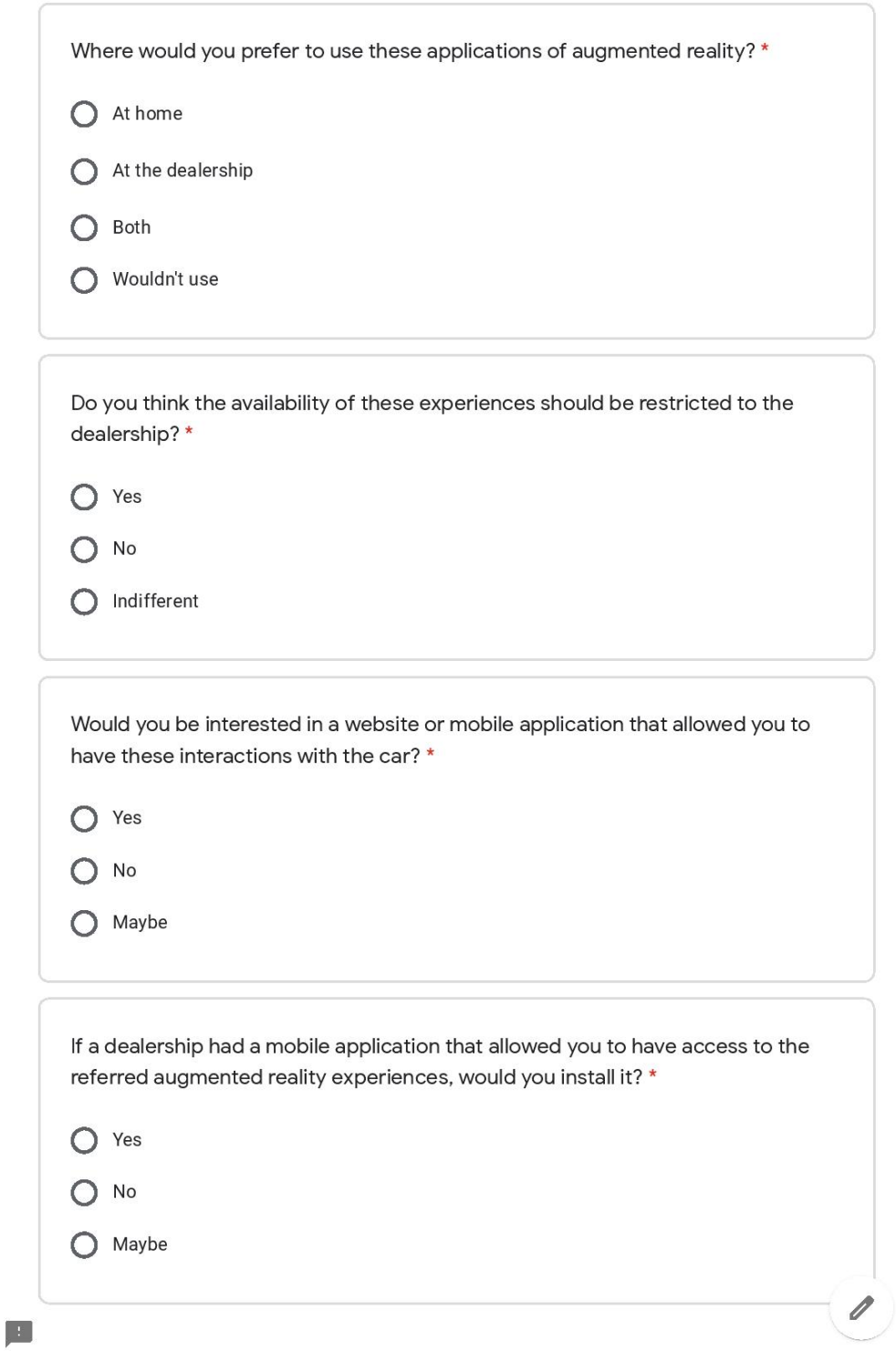


Figure A.9: English Survey - Augmented Reality (part three)

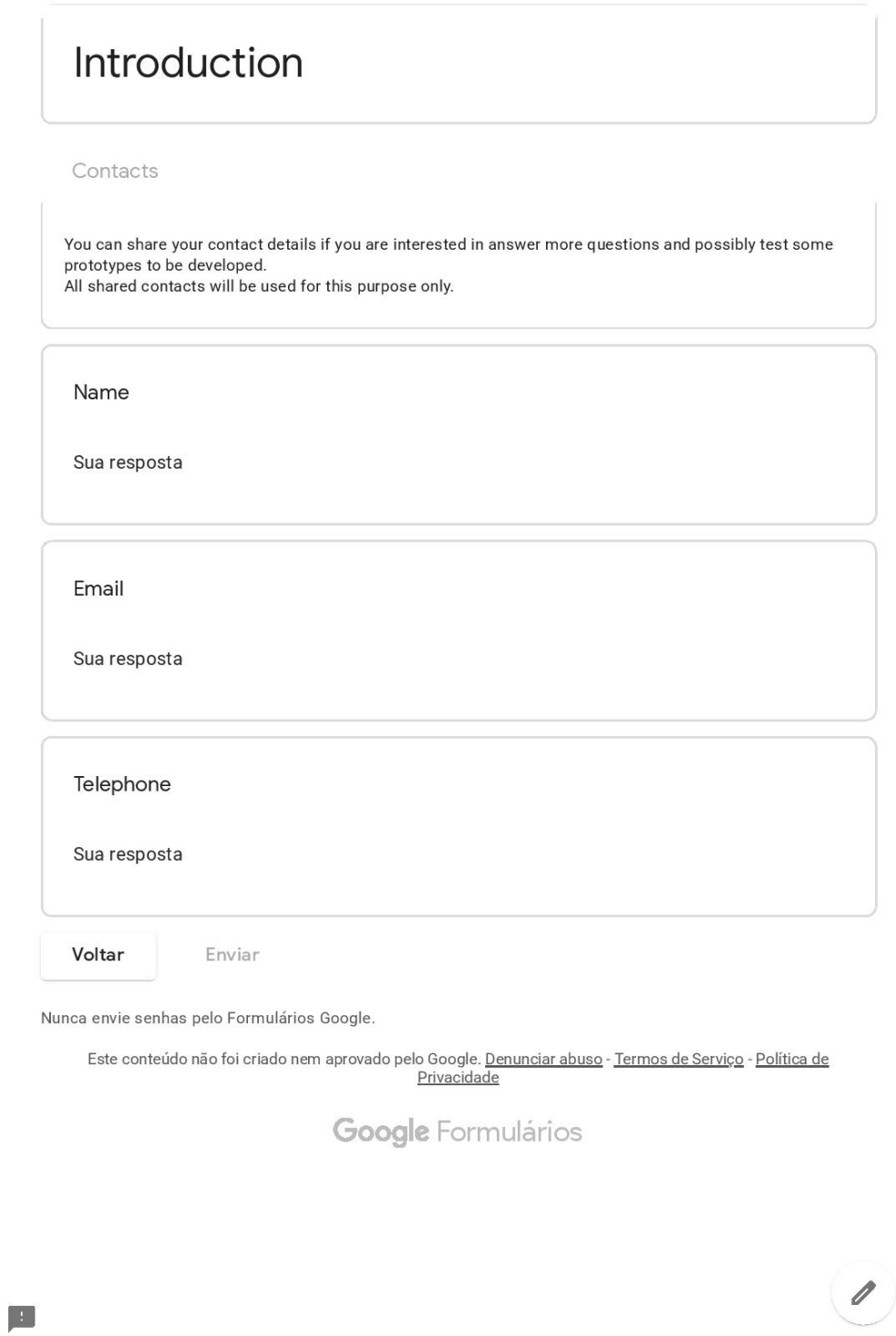
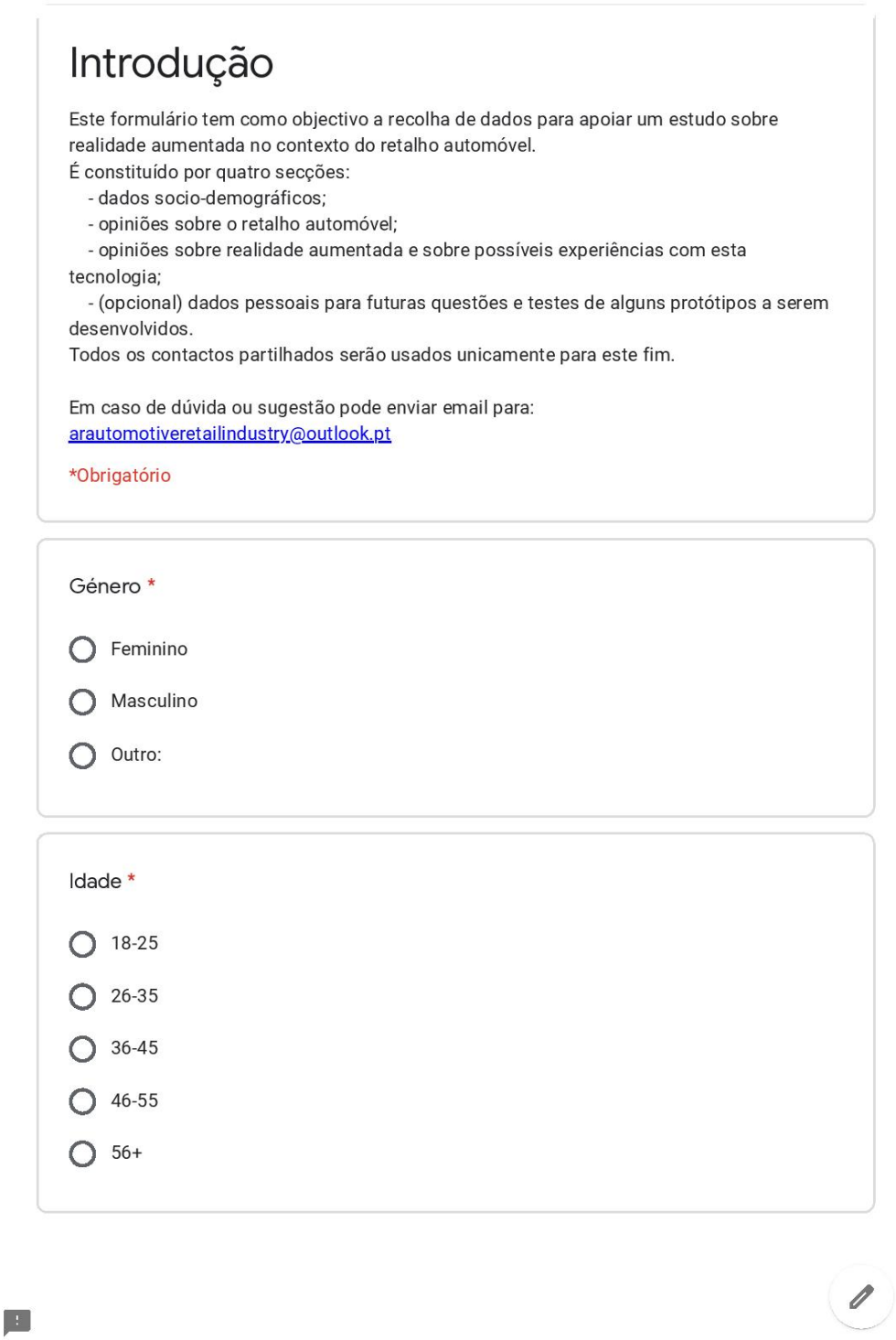


Figure A.10: English Survey - Contact

Appendix B

Portuguese Survey



Introdução

Este formulário tem como objectivo a recolha de dados para apoiar um estudo sobre realidade aumentada no contexto do retalho automóvel.
É constituído por quatro secções:
- dados socio-demográficos;
- opiniões sobre o retalho automóvel;
- opiniões sobre realidade aumentada e sobre possíveis experiências com esta tecnologia;
- (opcional) dados pessoais para futuras questões e testes de alguns protótipos a serem desenvolvidos.

Todos os contactos partilhados serão usados unicamente para este fim.

Em caso de dúvida ou sugestão pode enviar email para:
arautomotiveretailindustry@outlook.pt

*Obrigatório

Género *

- Feminino
- Masculino
- Outro:

Idade *

- 18-25
- 26-35
- 36-45
- 46-55
- 56+

Figure B.1: Portuguese Survey - Introduction (part one)

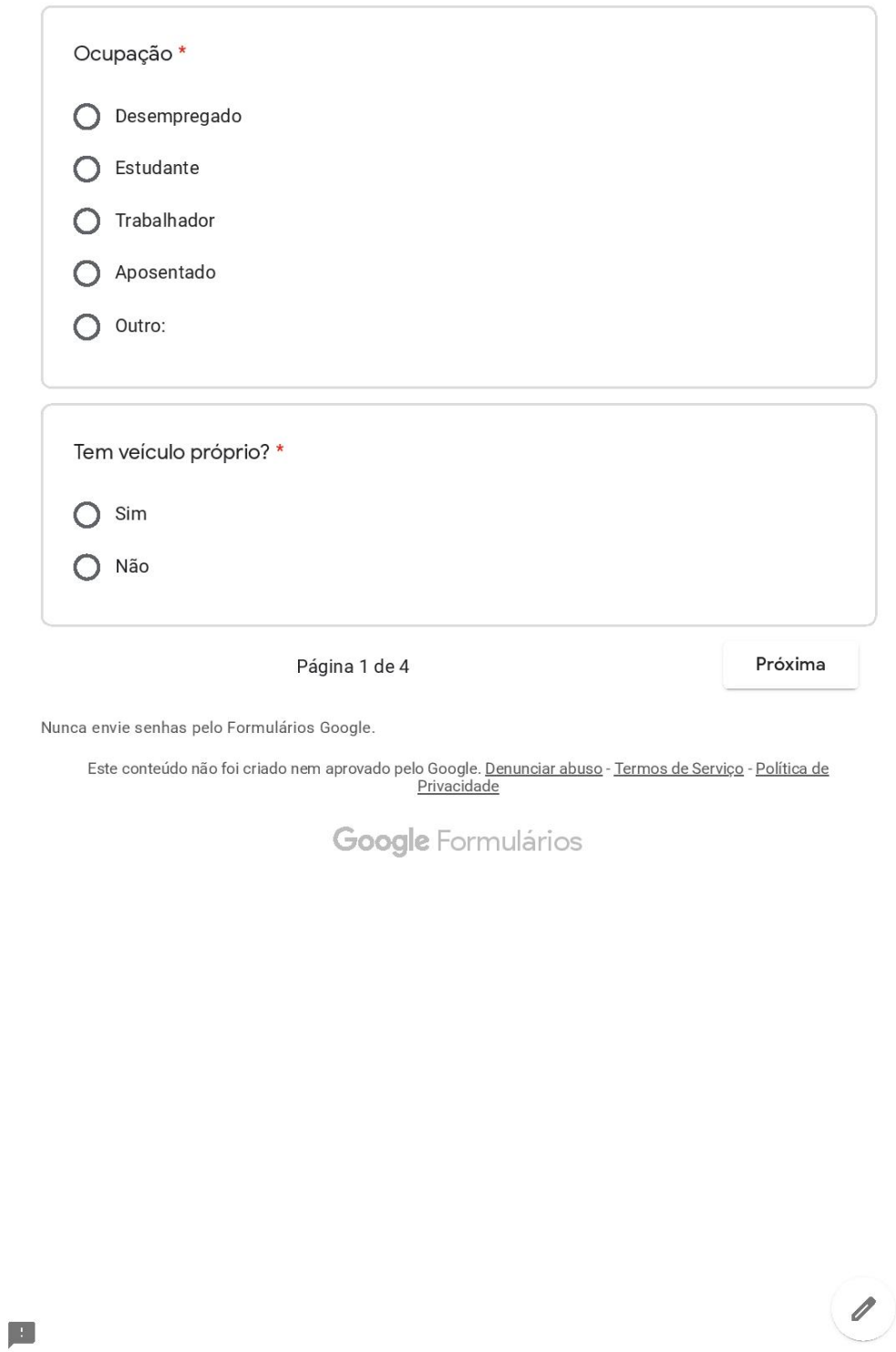


Figure B.2: Portuguese Survey - Introduction (part two)

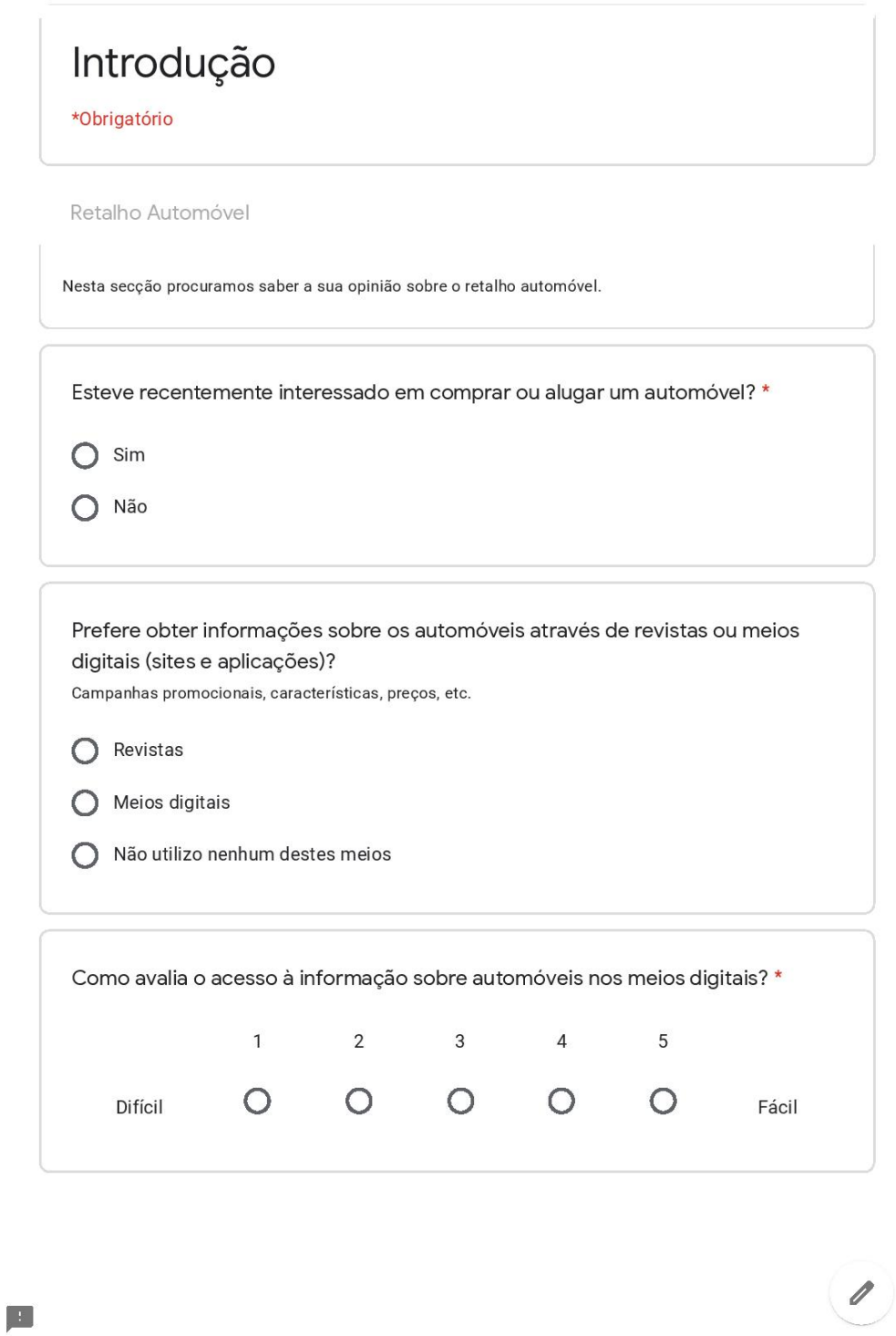


Figure B.3: Portuguese Survey - Auto-Retail (part one)

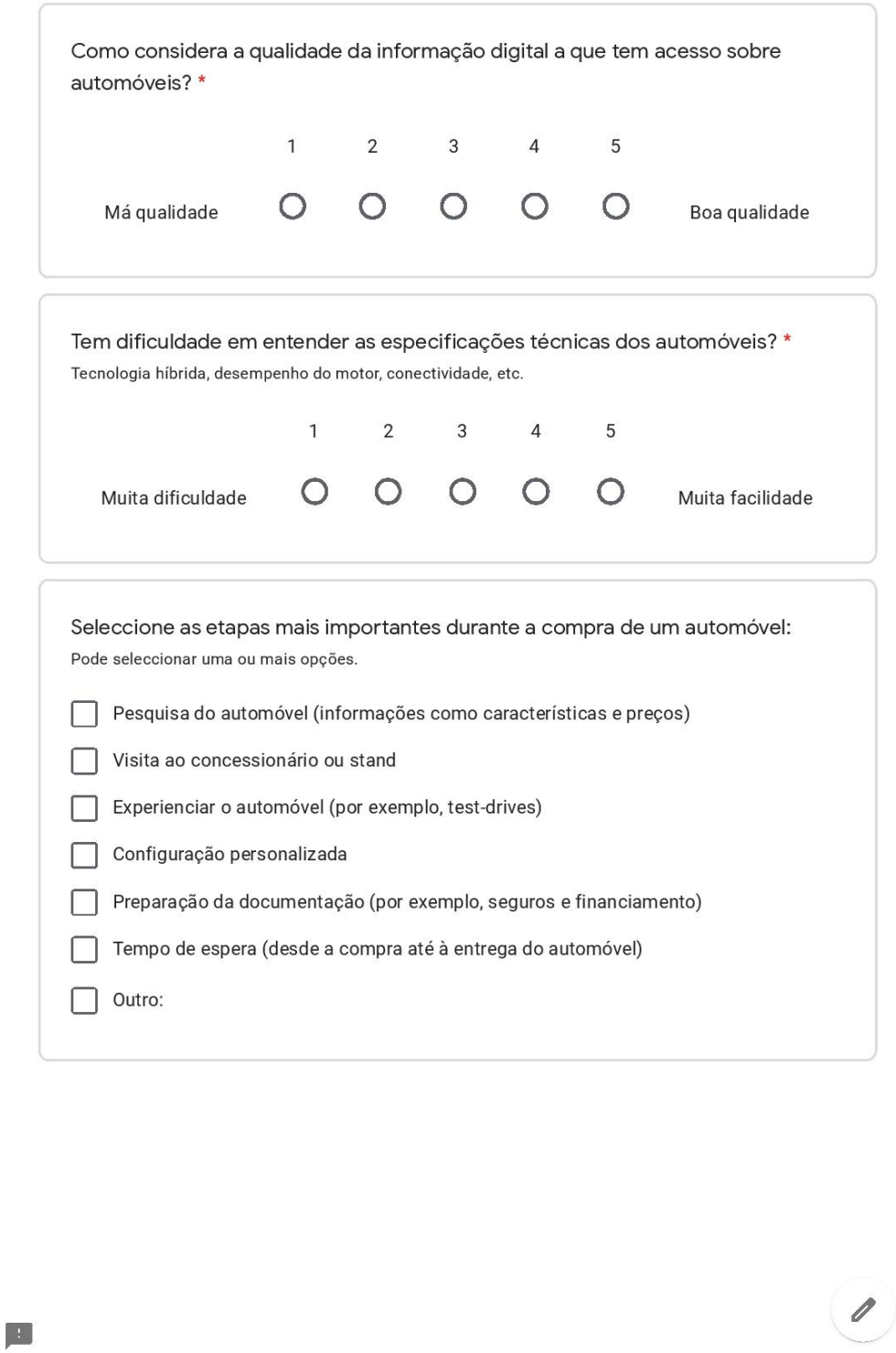


Figure B.4: Portuguese Survey - Auto-Retail (part two)

Figure B.5: Portuguese Survey - Auto-Retail (part three)

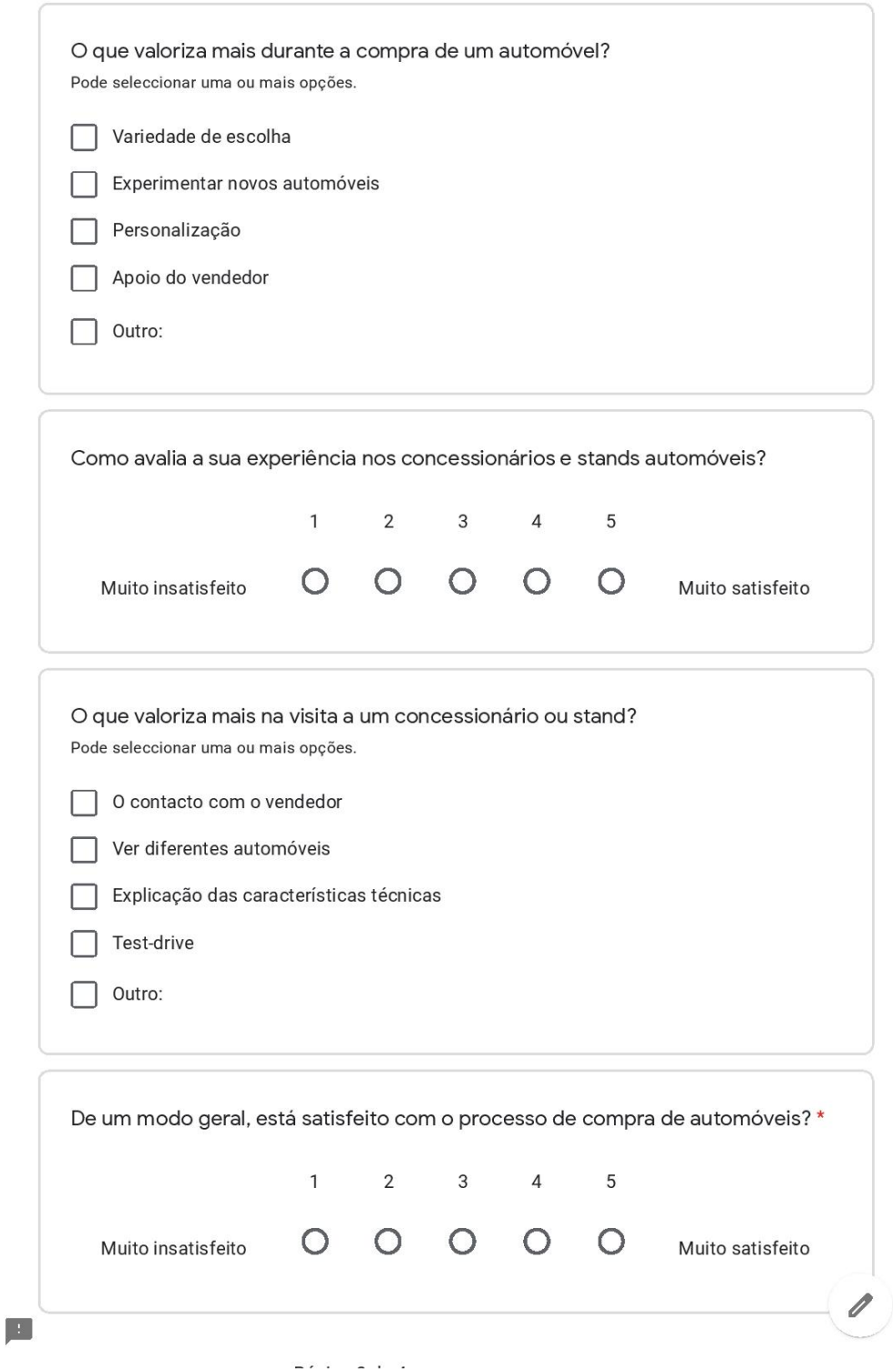


Figure B.6: Portuguese Survey - Auto-Retail (part four)

Introdução

*Obrigatório

Realidade Aumentada

Realidade aumentada é uma tecnologia que permite acrescentar em tempo real uma componente digital à nossa percepção da realidade.

Um video de exemplo:
https://www.youtube.com/watch?v=nTbSfyTbig8

O objectivo desta secção é perceber de que forma esta tecnologia pode ser integrada no retalho automóvel, de forma a melhorar a experiência do cliente dentro e fora do stand.

Exemplo de realidade aumentada

Figure B.7: Portuguese Survey - Augmented Reality (part one)

Já experimentou alguma aplicação de realidade aumentada? *

- ○ Sim
- ○ Não
- ○ Não tenho a certeza

Assinale as aplicações de realidade aumentada que têm potencial para melhorar a experiência de compra de automóveis: *

Pode seleccionar uma ou mais opções

☐ Visualizar o automóvel (exterior e interior)

☐ Demonstração interactiva das características técnicas do automóvel

☐ Outro:

☐ Personalização

Figure B.8: Portuguese Survey - Augmented Reality (part two)

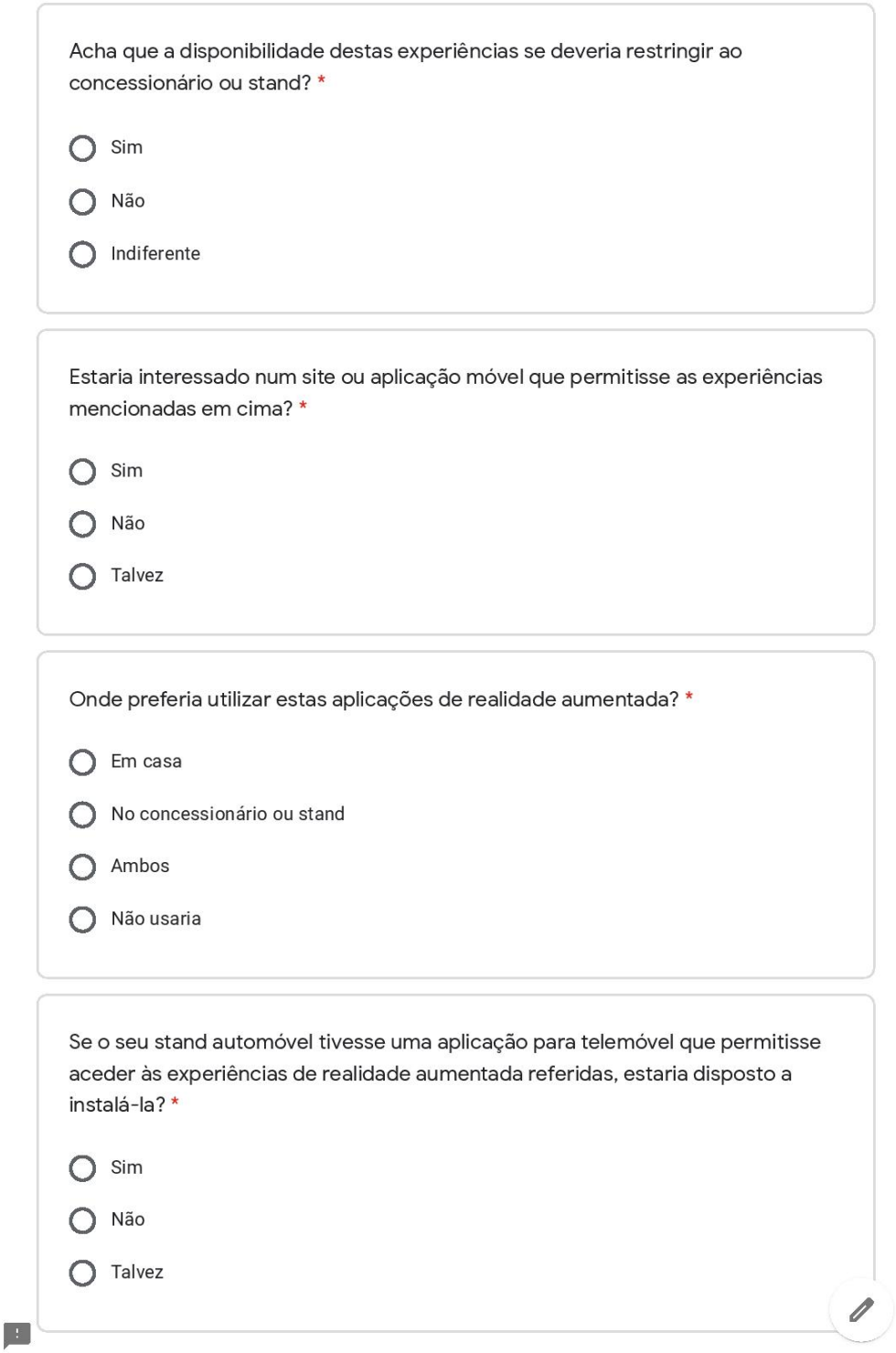


Figure B.9: Portuguese Survey - Augmented Reality (part three)

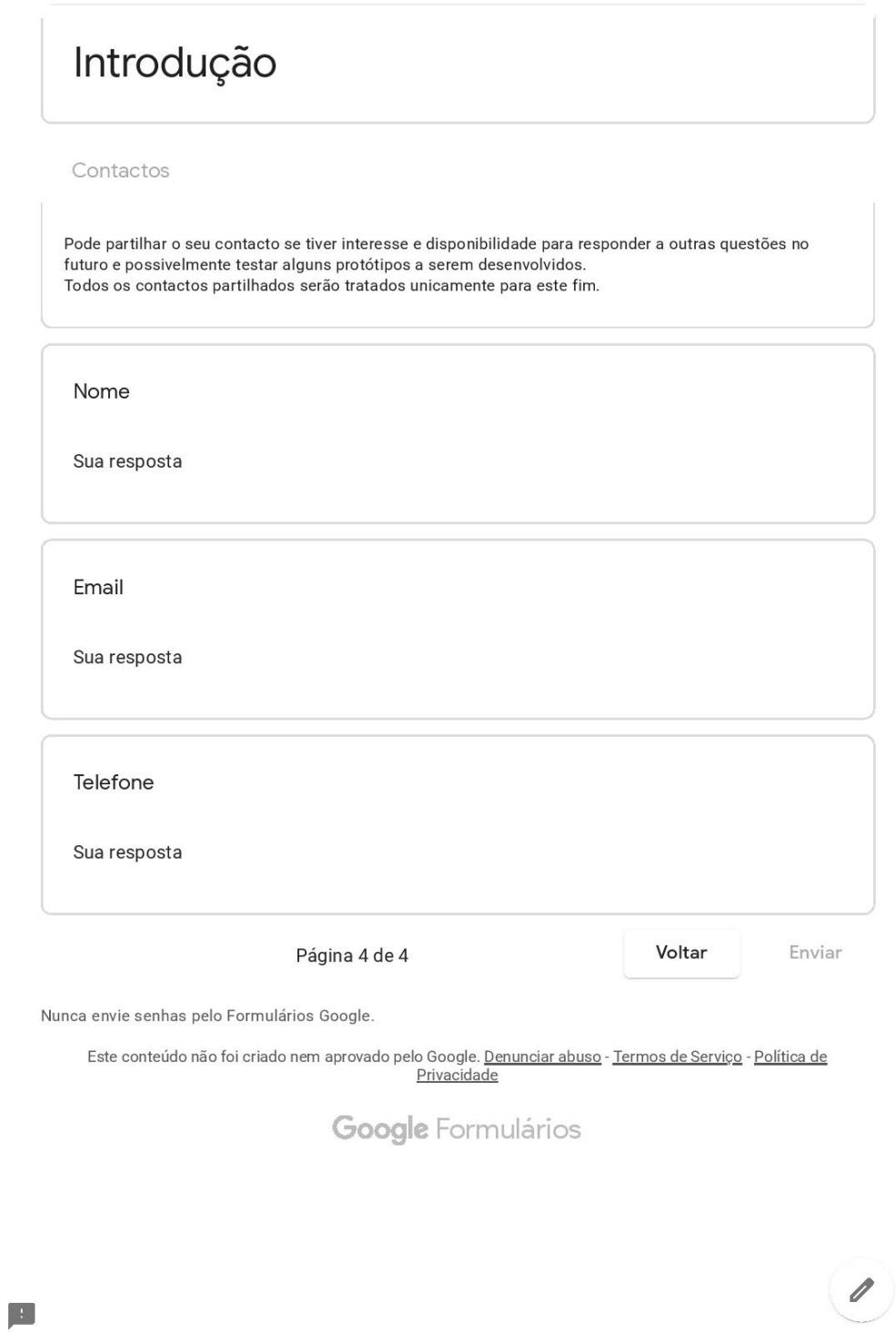


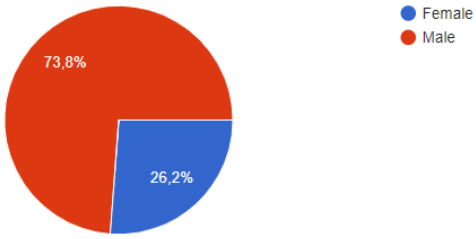
Figure B.10: Portuguese Survey - Contact

Appendix C

English Survey Results

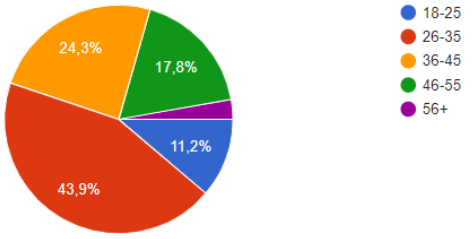
Gender

107 respostas



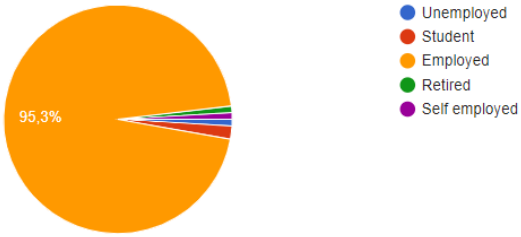
Age

107 respostas



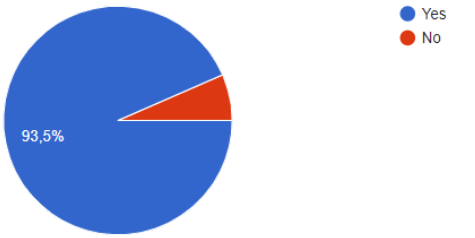
Occupation

107 respostas



Do you own a vehicle?

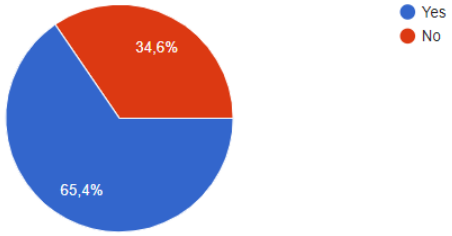
107 respostas



Automotive Retail

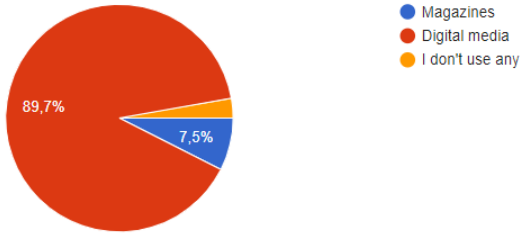
Have you recently been interested in buying or leasing a car?

107 respostas



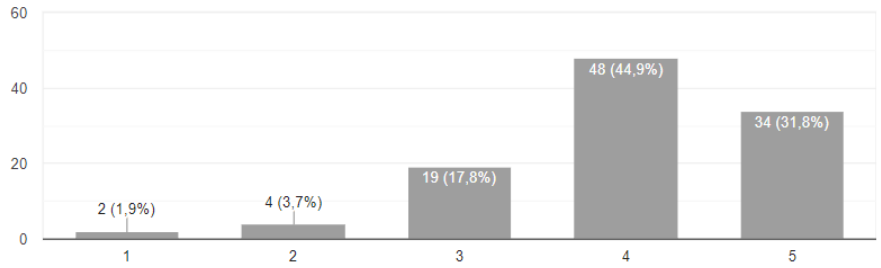
How do you prefer to get information about cars, through magazines or digital media (websites and applications)?

107 respostas



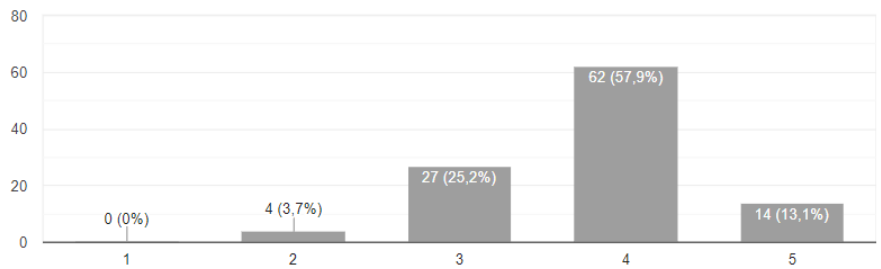
How do you rate the access to information about cars on digital media?

107 respostas



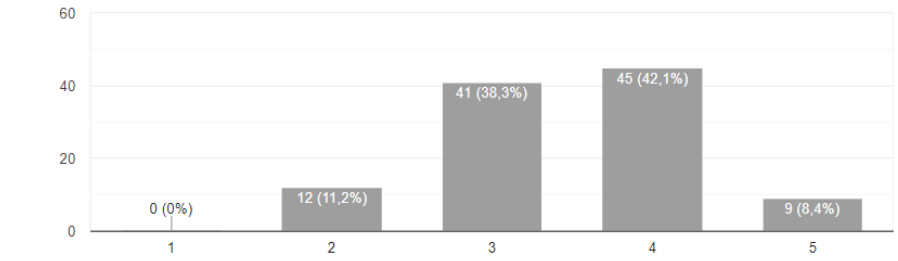
Regarding the quality of the car's digital information available, would you consider it:

107 respostas



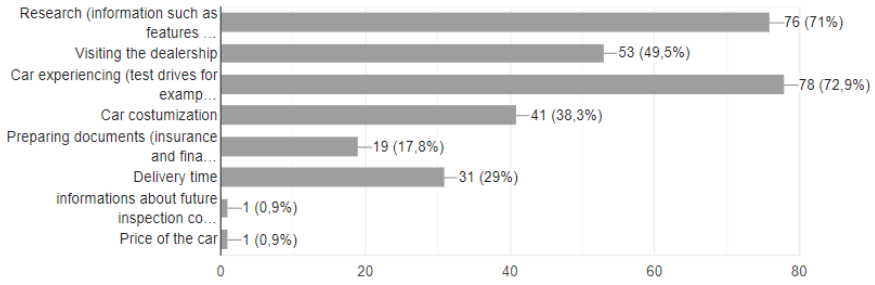
Regarding the difficulty in the understanding of the technical specifications of cars, would you say it is:

107 respostas

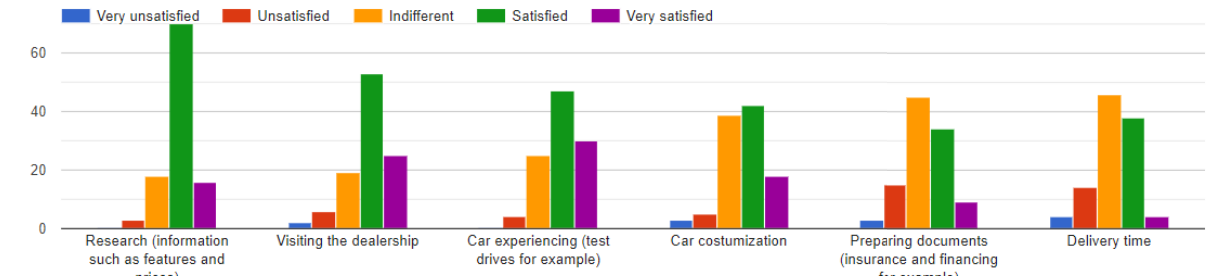


Which steps in buying a car are more important to you?

107 respostas

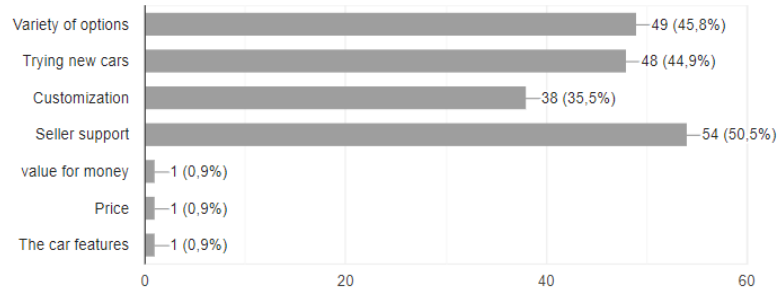


How satisfied are you with each of these steps?



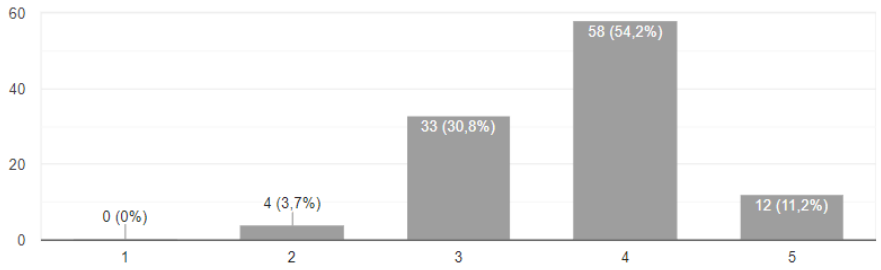
What do you value more during the purchase?

107 respostas



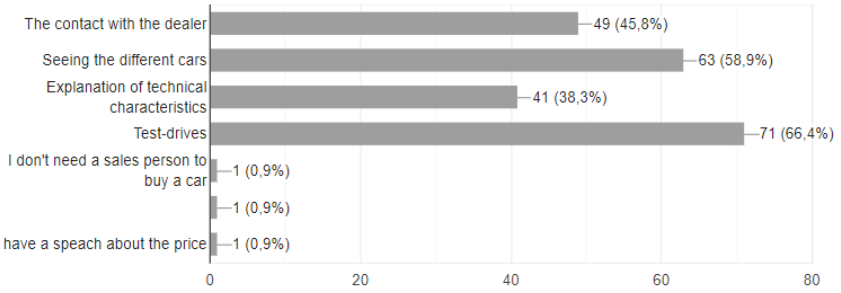
How do you evaluate your experience at car dealerships?

107 respostas



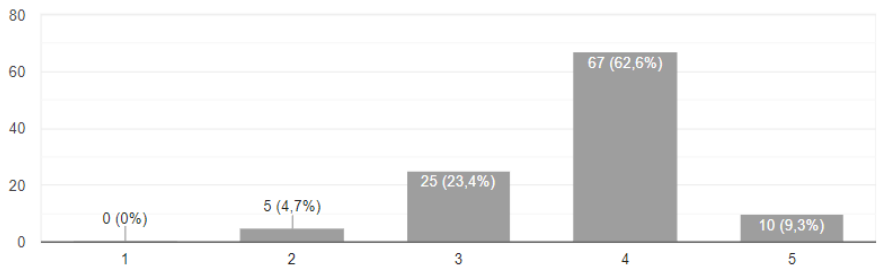
What do you value more while visiting the car dealership?

107 respostas



Generally, are you satisfied with the car buying process?

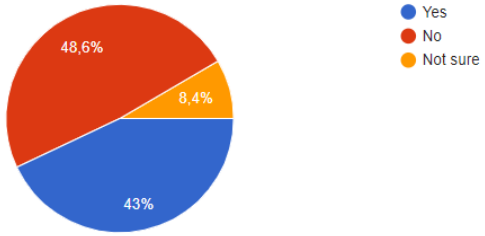
107 respostas



Augmented reality

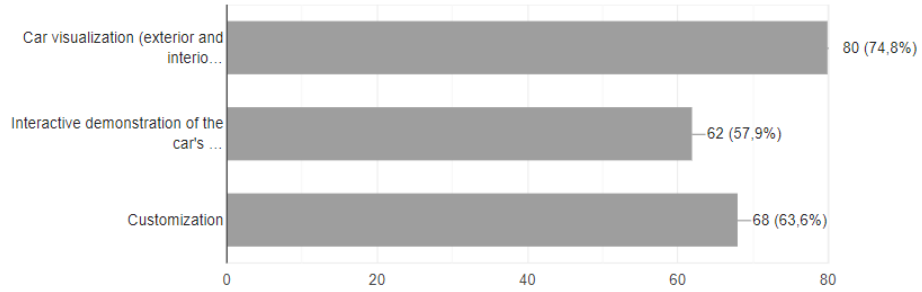
Have you tried any augmented reality applications?

107 respostas



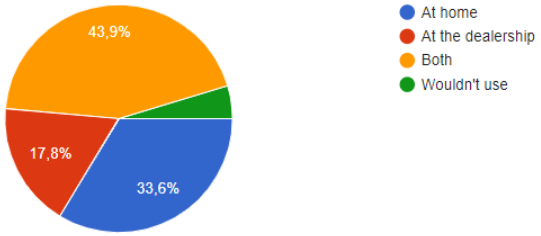
Select which augmented reality applications can improve the car buying experience:

107 respostas



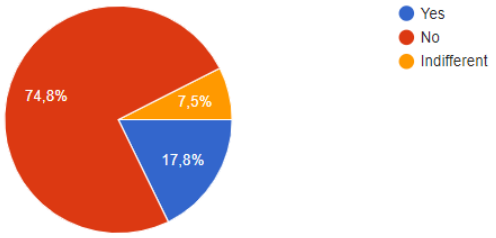
Where would you prefer to use these applications of augmented reality?

107 respostas



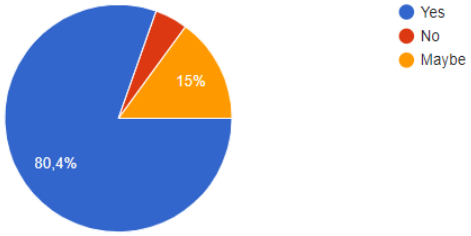
Do you think the availability of these experiences should be restricted to the dealership?

107 respostas



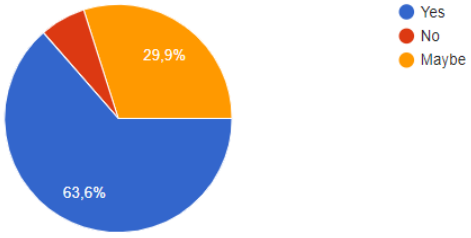
Would you be interested in a website or mobile application that allowed you to have these interactions with the car?

107 respostas



If a dealership had a mobile application that allowed you to have access to the referred augmented reality experiences, would you install it?

107 respostas

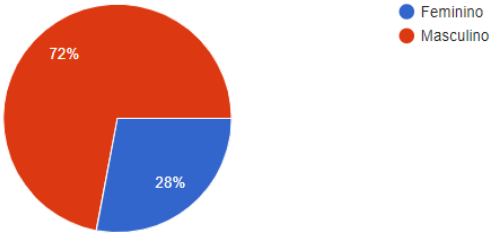


Appendix D

Portuguese Survey Results

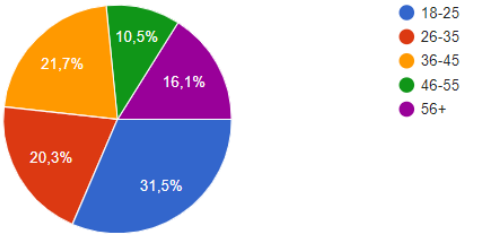
Género

143 respostas



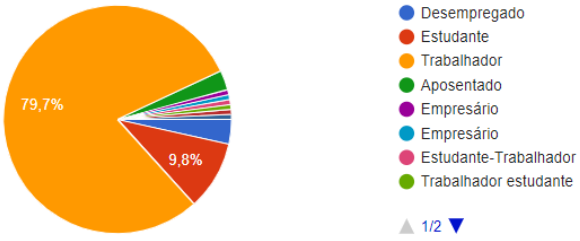
Idade

143 respostas



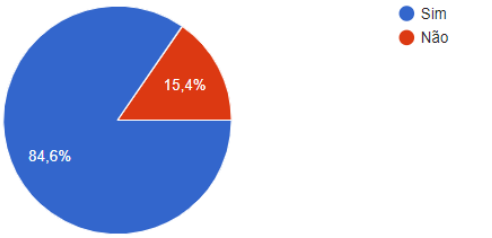
Ocupação

143 respostas



Tem veículo próprio?

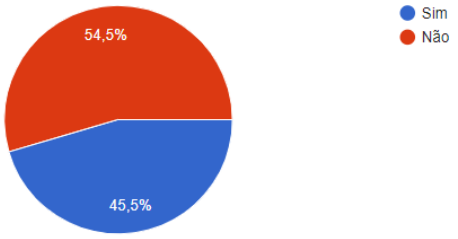
143 respostas



Retalho Automóvel

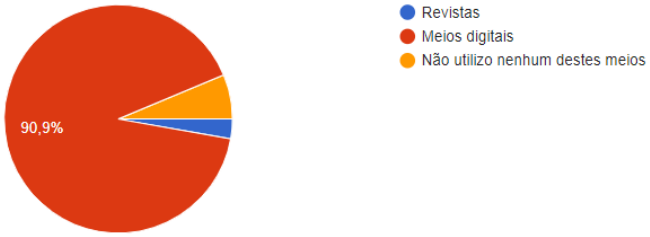
Esteve recentemente interessado em comprar ou alugar um automóvel?

143 respostas



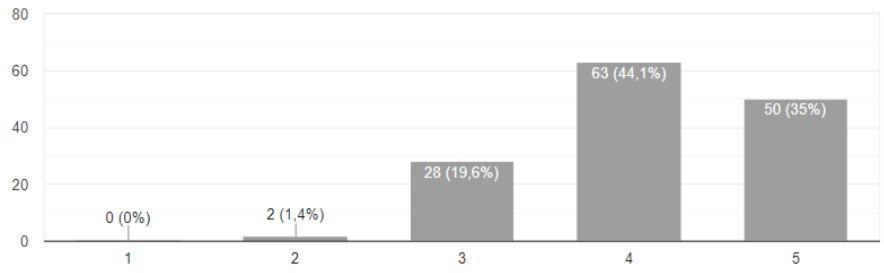
Prefere obter informações sobre os automóveis através de revistas ou meios digitais (sites e aplicações)?

143 respostas



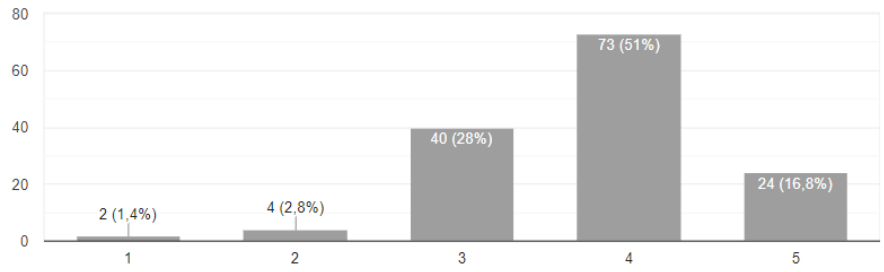
Como avalia o acesso à informação sobre automóveis nos meios digitais?

143 respostas



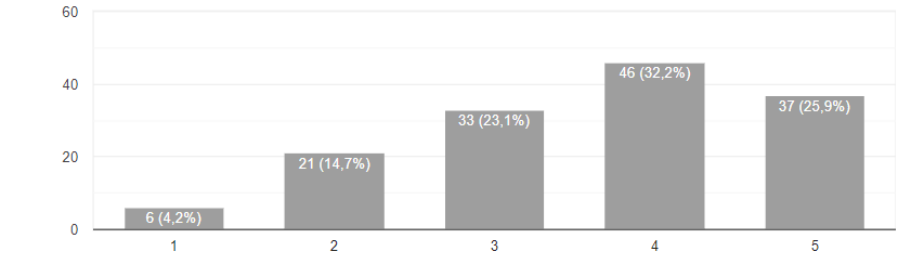
Como considera a qualidade da informação digital a que tem acesso sobre automóveis?

143 respostas



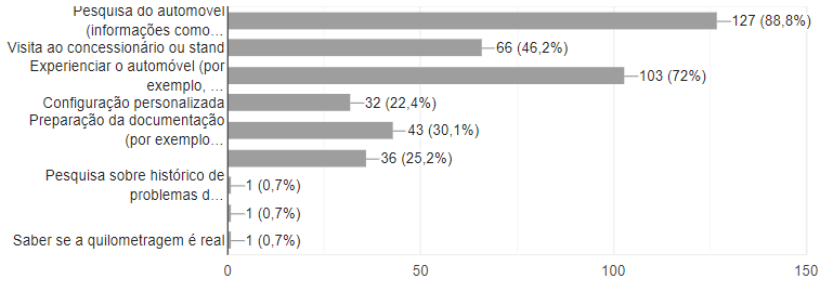
Tem dificuldade em entender as especificações técnicas dos automóveis?

143 respostas

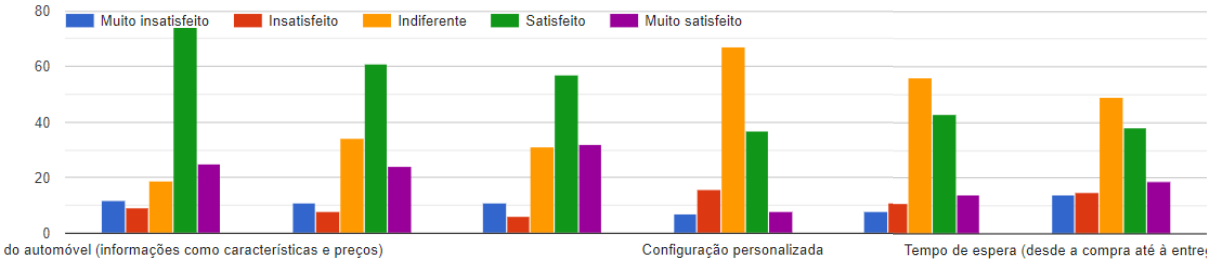


Seleccione as etapas mais importantes durante a compra de um automóvel:

143 respostas

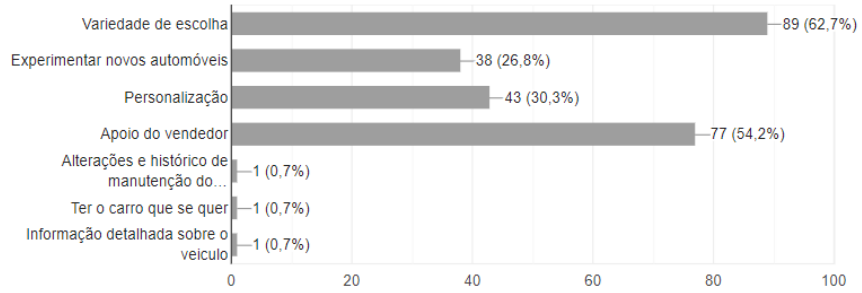


De acordo com a sua última experiência, qual foi o seu grau de satisfação para cada uma destas etapas?



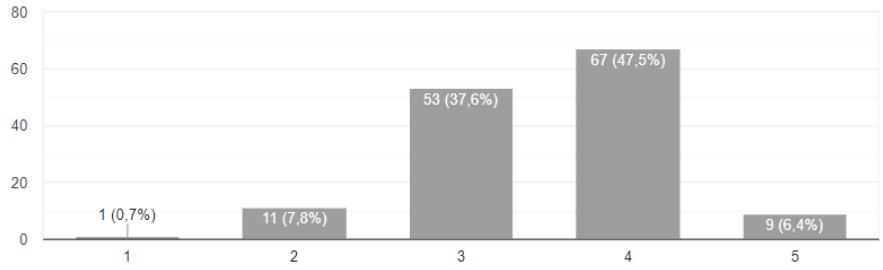
O que valoriza mais durante a compra de um automóvel?

142 respostas



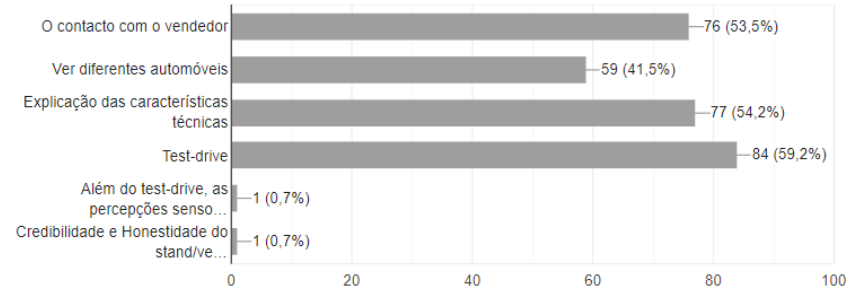
Como avalia a sua experiência nos concessionários e stands automóveis?

141 respostas



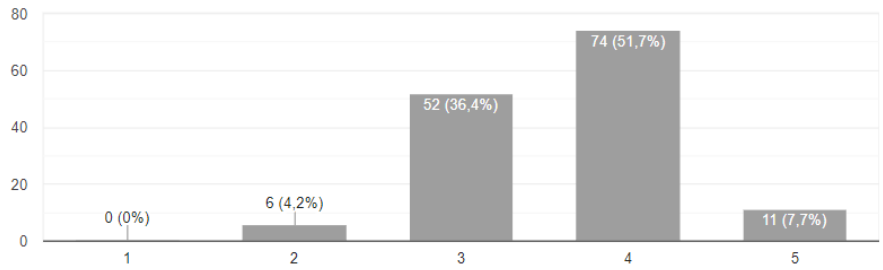
O que valoriza mais na visita a um concessionário ou stand?

142 respostas



De um modo geral, está satisfeito com o processo de compra de automóveis?

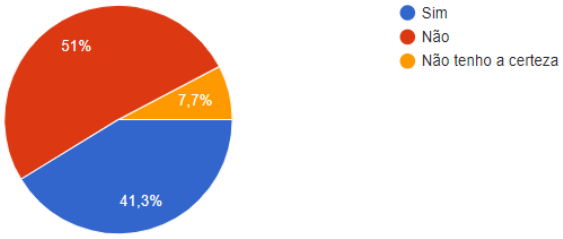
143 respostas



Realidade Aumentada

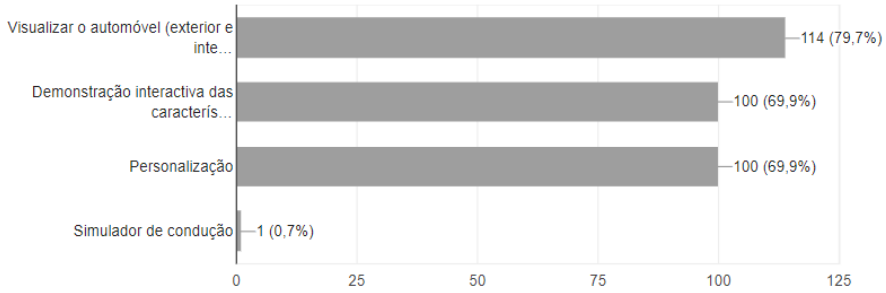
Já experimentou alguma aplicação de realidade aumentada?

143 respostas



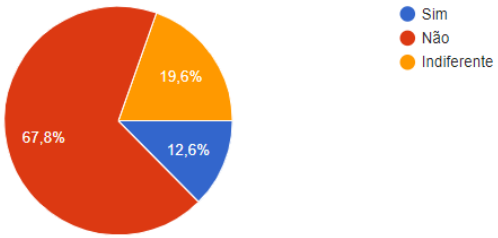
Assinale as aplicações de realidade aumentada que têm potencial para melhorar a experiência de compra de automóveis:

143 respostas



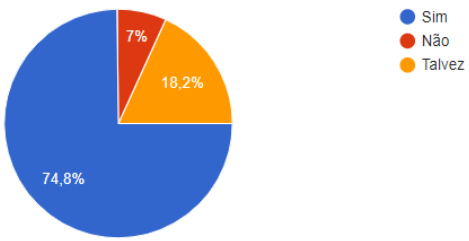
Acha que a disponibilidade destas experiências se deveria restringir ao concessionário ou stand?

143 respostas



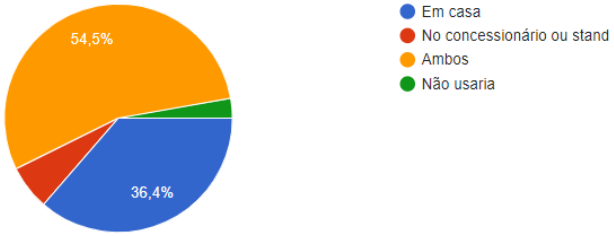
Estaria interessado num site ou aplicação móvel que permitisse as experiências mencionadas em cima?

143 respostas



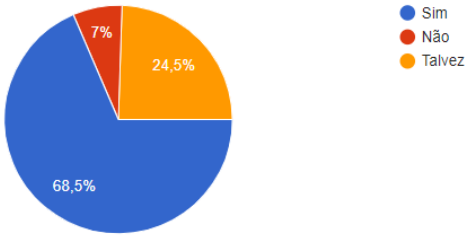
Onde preferia utilizar estas aplicações de realidade aumentada?

143 respostas



Se o seu stand automóvel tivesse uma aplicação para telemóvel que permitisse aceder às experiências de realidade aumentada referidas, estaria disposto a instalá-la?

143 respostas



Appendix E

Consent Forms

Consent for Participation in Research

Title: Research about the use of augmented reality technology in the automotive retail industry, specifically in sales and marketing.

Introduction: The purpose of this form is to provide information to the possible participant that may affect your decision as to whether or not to participate in this research study. Your participation is voluntary. Read the information below and ask any questions you might have before deciding whether or not to take part. If you decide to be involved in this study, this form will be used to record your consent.

Purpose of the Study: You have been asked to participate in a research study about augmented reality applications for car marketing. The purpose of this study is to compare and evaluate the user experience of three applications available to the public and analyse the effectiveness in creating an engaging and informative marketing experience.

What will you be asked to do? If you agree to participate in this study, you will be asked to complete three steps: (1) fill in a self-administered questionnaire online, (2) interact with a system for and (3) fill in a second questionnaire, regarding your experience. This study will take approximately 1 hour. Your participation in step 2 will be video recorded.

What are the risks involved in this study? There are no foreseeable risks in this study.

What are the possible benefits of this study? While we cannot compensate you for your time, your participation will be valuable to our project and will help us broaden our understanding of the topic under investigation. The contribution of this project to science and society can only be achieved with your help.

How will your privacy and confidentiality be protected? You will remain anonymous and your answers are confidential. The data resulting from your participation may be made available to other researchers involved in the study. In these cases, the data will contain no identifying information that could associate it with you, or with your participation in any study.

Whom to contact with questions about the study? Prior, during or after your participation you can contact the researcher Mariana Guimarães at arautomotiveretailindustry@outlook.com for any questions or concerns.

Participant signature Date

_____ _____

As a representative of this study, I have explained the purpose, procedures, benefits, and the risks involved in this research study.

Researcher signature Date

_____ _____

Consent for Participation in Research

Title: Research about the use of augmented reality technology in the automotive retail industry, specifically in sales and marketing.

Introduction: The purpose of this form is to provide information to the possible participant that may affect your decision as to whether or not to participate in this research study. Your participation is voluntary. Read the information below and ask any questions you might have before deciding whether or not to take part. If you decide to be involved in this study, this form will be used to record your consent.

Purpose of the Study: You have been asked to participate in a research study about augmented reality applications for car marketing. The purpose of this study is to evaluate the user experience of a prototype of an application and analyse the effectiveness in creating an engaging and informative marketing experience.

What will you be asked to do? If you agree to participate in this study, you will be asked to complete two steps: (2) interact with the prototype and (3) answer a few questions at the end regarding your experience. This study will take approximately 30 minutes. Your participation in step 2 will be video recorded.

What are the risks involved in this study? There are no foreseeable risks in this study.

What are the possible benefits of this study? While we cannot compensate you for your time, your participation will be valuable to our project and will help us broaden our understanding of the topic under investigation. The contribution of this project to science and society can only be achieved with your help.

How will your privacy and confidentiality be protected? You will remain anonymous and your answers are confidential. The data resulting from your participation may be made available to other researchers involved in the study. In these cases, the data will contain no identifying information that could associate it with you, or with your participation in any study.

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Participant signature Date

_____ _____

As a representative of this study, I have explained the purpose, procedures, benefits, and the risks involved in this research study.

Researcher signature Date

_____ _____

Appendix F

Usability Tests Porsche

Metrics		Porsche						
		Task 1 - position	Task 2 - colour	Task 3 - rims	Task 4 - open	Task 5 - motor	Task 6 - interior	Task 7 - contact
Quatitative	Successful Task Completion	☑	☑	☑	☑	☑	☑	☑
	Critical Errors	1	0	0	0	0	1	0
	Non-Critical Errors	0	0	0	1	0	1	0
Subjective	Satisfaction (0-5)	2	5	5	5	5	4	5
	Ease of use (0-5)	2	5	5	5	5	2	4
	Ease finding information (0-5)	4	5	5	4	5	1	4
	Likes, Dislikes and Recommendations	There was a dificulty in positioning	doubt in whether the colours were true to the real colours		it doesn't allow to see the interior		Suggestion: a menu option that changes the camera directly to the interior of the car, due to the difficulty in positioning of the car	fear of leaving the application without confirmation

Metrics		Porsche						
		Task 1 - position	Task 2 - colour	Task 3 - rims	Task 4 - open	Task 5 - motor	Task 6 - interior	Task 7 - contact
Quatitative	Successful Task Completion	☐	☑	☑	☐	☑	☑	☑
	Critical Errors	1	0	0	1	0	0	0
	Non-Critical Errors	0	0	0	0	1	1	
Subjective	Satisfaction (0-5)	0	5	5	0	0	5	5
	Ease of use (0-5)	0	5	5	0	1	2	5
	Ease finding information (0-5)	3	5	5	1	2	2	5
	Likes, Dislikes and Recommendations	There was a dificulty in positioning			only found the place to open with help from the moderator			

Metrics		Porsche						
		Task 1 - position	Task 2 - colour	Task 3 - rims	Task 4 - open	Task 5 - motor	Task 6 - interior	Task 7 - contact
Quatitative	Successful Task Completion	☑	☑	☑	☑	☑	☑	☑
	Critical Errors	0	1	0	0	0	0	0
	Non-Critical Errors	0	0	0	1	0	1	0
Subjective	Satisfaction (0-5)	5	5	5	5	5	5	5
	Ease of use (0-5)	5	3	5	4	4	5	5
	Ease finding information (0-5)	5	5	5	4	4	4	5
	Likes, Dislikes and Recommendations	Commented that in open and bigger spaces the experience would be better	The menu disappeared and it was necessary to restart the scene			it was noted that was lagging		Even though it saved the configuration made in AR, it missed a lot of configurations like interiors.

Appendix G

Usability Tests VW Touareg

Metrics		Experience VW Touareg					
		Task 1 - position	Task 2 - colour	Task 3 - accessories	Task 4 - features	Task 5 - interior	Task 6 - specs
Quatitative	Successful Task Completion	☑	☑	☑	☑	☑	☑
	Critical Errors	0	0	0	0	1	0
	Non-Critical Errors	0	0	0	0	0	0
Subjective	Satisfaction (0-5)	5	5	4	5	1	4
	Ease of use (0-5)	5	4	3	5	2	4
	Ease finding information (0-5)	5	4	4	5	2	4
	Likes, Dislikes and Recommendations		Noted some difficulties with the menu	It should give more feedback that the accessory was applied	Liked the demonstrations	Suggestion: It should give some indication on how to explore the interior	

Metrics		Experience VW Touareg					
		Task 1 - position	Task 2 - colour	Task 3 - accessories	Task 4 - features	Task 5 - interior	Task 6 - specs
Quatitative	Successful Task Completion	☑	☑	☑	☑	☑	☑
	Critical Errors	0	0	0	0	0	0
	Non-Critical Errors	1	0	0	0	1	0
Subjective	Satisfaction (0-5)	5	5	5	5	5	5
	Ease of use (0-5)	5	5	5	5	3	5
	Ease finding information (0-5)	4	5	5	5		4
	Likes, Dislikes and Recommendations				The icons don't give information enough and should have text	It's not obvious that the vehicle wouldn't move	

Metrics		Experience VW Touareg					
		Task 1 - position	Task 2 - colour	Task 3 - accessories	Task 4 - features	Task 5 - interior	Task 6 - specs
Quatitative	Successful Task Completion	☑	☑	☑	☑	☑	☑
	Critical Errors	0	0	0	0	0	0
	Non-Critical Errors	0	0	0	0	1	0
Subjective	Satisfaction (0-5)	5	5	5	5	5	5
	Ease of use (0-5)	5	5	4	5	3	5
	Ease finding information (0-5)	5	5	4	5		5
	Likes, Dislikes and Recommendations			lack of feedback			

Appendix H

Usability Tests VW Nivus

Metrics		VW Experience Nivus							
		Task 1 - version	Task 2 - position	Task 3 - colour	Task 4 - rims	Task 5 - interior	Task 7 - features	Task 6 - mechanics	Task 7 - contact
Quatitative	Successful Task Completion	☑	☑	☑	☑	☑	☑	☑	☑
	Critical Errors	0	2	0	0	0	0	1	0
	Non-Critical Errors		1			1	1		
Subjective	Satisfaction (0-5)	5	1	5	4	4	4	5	5
	Ease of use (0-5)	5	0	5	5	2	5	5	5
	Ease finding information (0-5)	5	5	5	5	2	5	5	5
	Likes, Dislikes and Recommendations	Suggestion: change the menu name	Observation: problems with the objet staying in place, it would "slide away"				Observations: hard navigation but good detail and summarize information		

Metrics		VW Experience Nivus							
		Task 1 - version	Task 2 - position	Task 3 - colour	Task 4 - rims	Task 5 - interior	Task 7 - features	Task 6 - mechanics	Task 7 - contact
Quatitative	Successful Task Completion	☑	☑	☑	☑	☑	☑	☑	☑
	Critical Errors		0						
	Non-Critical Errors					2	2	2	
Subjective	Satisfaction (0-5)	3	5	5	5	2	3	2	5
	Ease of use (0-5)	2	5	5	4	2	3		
	Ease finding information (0-5)	3	5	5	4	1	3	1	
	Likes, Dislikes and Recommendations	Hard to find in the middle of all options		Suggestion: more colours and other textures (mat and chroma)		Suggestion: menu button to get in the vehicle and see the interior	spots aren't clear if are information or action	few information	

Metrics		VW Experience Nivus							
		Task 1 - version	Task 2 - position	Task 3 - colour	Task 4 - rims	Task 5 - interior	Task 7 - features	Task 6 - mechanics	Task 7 - contact
Quatitative	Successful Task Completion	☑	☑	☑	☑	☑	☑	☑	☑
	Critical Errors	0	0	0	0	1	0	0	0
	Non-Critical Errors	0	0	0	0	1	0	0	0
Subjective	Satisfaction (0-5)	4	4	4	4	4	4	4	3
	Ease of use (0-5)	5	4	5	5	3	5	5	5
	Ease finding information (0-5)	4	3	5	5		5	5	5
	Likes, Dislikes and Recommendations					Suggestion: add an indication that incentivizes to walk and explore the inside of the car	it should be more realistic	Suggestion: more detail	

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