TOWARDS A FRAMEWORK FOR THE EARLY-STAGE ASSESSMENT OF INFOTAINMENT SYSTEMS FOR LUXURY CARS

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Abstract

The design of infotainment systems for luxury cars is a complicated task as consumer expectations are high and the possibilities of the automotive systems are limited. As the subjective experience of consumers plays an important role in the perceived quality of the system, designing for high-quality user experiences (UX) has become an important focus of attention. However, no clear guidelines on designing for high-quality UX of infotainment systems for luxury cars exist. Therefore, this thesis aimed to create a framework for evaluating the UX of infotainment systems in collaboration with ART, designer and manufacturer of infotainment systems for luxury cars. This framework will help companies like ART to guide the design process and the evaluation of these systems.

First, a systematic literature review was conducted to extrapolate the most important dimensions of UX for infotainment systems, representing the most important aspects to consider when evaluating the quality of experience of infotainment systems. In addition, the methods used to assess these dimensions were identified. Based on these results, a preliminary framework for the assessment of (luxury) infotainment systems was proposed. The second phase of this research aimed to validate this preliminary framework by conducting a survey among designers of infotainment systems and consumers of both luxury and regular cars. These three groups were distinguished to explore potential differences between their viewpoints on the importance of the dimensions (i.e., mental models).

Overall, the results showed that respondents appeared to agree with the dimensions extrapolated from the literature. However, differences could be observed regarding the relative importance of the dimensions for the three groups of respondents, suggesting that there are differences between their mental models. The framework was refined based on the results of the survey and potential items for assessing these dimensions were proposed. Future research should try to include more data on luxury consumers and extend the framework by creating a questionnaire based on the items proposed.

Keywords: User Experience, Design, Assessment, Luxury, Infotainment systems, Cars

CONTENTS

1. Introduction 5
1.1. Defining UX in the Context of IVIS 6
1.1.1. Designing for High-Quality UX 7
1.2. UX in the Context of Luxury IVIS 9
1.3. UX Assessment of IVIS 12
1.3.1. Standardized Questionnaires for UX assessment 13
1.4. Aim of the Thesis 15
2. Phase 1. Methods of the Literature Review 17
2.1. Study Design 17
2.2. Research Questions 17
2.3. Eligibility Criteria 17
2.4. Search Strategy 18
3. Results of Literature Review 19
3.1. Potentially Relevant Dimensions of UX for Infotainment Systems 34
3.2. Frequency of Assessment of Potential Dimensions 38
3.3. Methods used to Assess Potential Dimensions of UX 39
4. Insights from the Literature Review 40
4.1. Potential Dimensions of UX in the Context of Luxury IVIS 40
4.2. Methods of Assessment 42
4.3. Initial Framework based on Literature Review 45
4.4. Further Validation of Framework 46
5. Phase 2. Methods of Survey Study 48
5.1. Survey Design 48
5.2. Survey Distribution 48
5.3. Measurements and Analysis 49
6. Results of Survey Study 51
6.1. Demographics of Respondents 51
6.2. Consensus on Potential Dimensions 51
6.3. Relative Importance of Potential Dimensions 52
6.3.1. Priorities 53
6.3.2. Rankings 55
6.3.3. Probabilities 56
6.4. Comments 60
7. Discussion 61
7.1. Survey Results 61
7.1.1. Agreement with the Proposed Dimensions 61

7.1.2. Relative Importance of Dimensions 63
7.2. Redesigned Framework Based on Survey 65
7.3. Limitations 68
7.4. Directions for Future Research 69
References 71
Appendix A 81
Appendix B 84
Appendix C 111

1. INTRODUCTION

In-vehicle infotainment systems (IVIS) are the technological systems in the car that provide "information" and "entertainment" services to the car occupants (Sen & Sener, 2020). After introducing the first clusters of gauges in cars in the 1920s, allowing drivers to read all information in one glance, more and more advanced in-vehicle interfaces have been developed (Akamatsu et al., 2013). The current infotainment systems of luxury vehicles include functionalities such as navigation, media, radio, telephone, and settings in addition to vehicle information. Some of these functionalities already existed as analogical information systems that were mounted on the car. Current infotainment systems are often integrated digital systems that make the different infotainment functionalities accessible through one unified interface. These interfaces may be distributed over multiple displays placed in the centre console or in the shape of a head-up display. Some cars are even equipped with special displays for passenger interaction (Berger et al., 2021; Sen & Sener, 2020). As more and more functionalities are added to the system and the interface is spread over multiple displays, designing these infotainment systems becomes an increasingly complex task (Prabhakar & Biswas, 2021).

This task becomes even more complex by the development of new technologies and the widespread use of smart technologies (e.g., smartphones) on a daily basis, causing consumers to have high expectations and a desire for instant satisfaction (Young & Zhang, 2015). Users no longer settle for an infotainment system that has just a few core functions but expect a large number of functions to be integrated with the car's infotainment system (Wei et al., 2016). As Zheng and colleagues (2007) suggest, consumers nowadays are asking for cars to be equipped with multifunctional systems for navigation, communication, information and entertainment. The user's expectations result in an increased pressure on car manufacturers to keep increasing the possibilities offered by the IVIS.

However, the limitations of automotive systems make it hard to live up to these expectations. First of all, automotive processors are less powerful than their consumer counterparts and IVIS need to be designed for the lifetime of the vehicle, which is much longer than that of consumer devices such as smartphones (Macario et al., 2009). In addition, interacting with the system should be safe, so complex menus requiring long sequences of interaction should be avoided. Altogether, the limitations of automotive systems require complicated design solutions for IVIS to live up to consumers' expectations.

This might be even more challenging in the context of luxury cars. Luxury products are expected to offer superior product qualities and performance compared to non-luxury

products (Vigneron & Johnson, 2004). Consequently, consumers of luxury cars are likely to have higher expectations of the quality of the infotainment system. This was demonstrated in a study by Aladdin and colleagues (2016), who showed that consumers of luxury cars tolerate less noise in the vehicle cabin compared to regular car owners. Luxury consumers seem to expect a lower level of noise and thus a more pleasant experience. This indicates that consumers of luxury cars generally have higher expectations regarding the quality of the experience compared to consumers of regular products. These elevated expectations of luxury consumers make designing IVIS for luxury cars an even more complicated task.

Taken together, the design of IVIS for luxury cars is a complex task since many functionalities need to be integrated over multiple displays, limitations regarding safety and automotive processors need to be taken into account, and (luxury) consumers' expectations are high. Designers of IVIS should make sure that the quality of the infotainment system meets the user's expectations. According to Oliveira and colleagues (2021) companies nowadays do not only design to provide a good driving performance but to also offer unique and satisfactory user experiences. In other words, the quality of the system does not only depend on the objective performance of the system, but also on the subjective experience of the user. The importance of designing for user experience is recognised by designers and researchers, as reflected by an increase in studies assessing aspects of the subjective experience by the user in the automotive field (Kun et al., 2016). The subjective experience of the user is thus important to take into account when designing the IVIS of a luxury car, since this is a major contributor to the intentions to purchase a car.

1.1. Defining UX in the Context of IVIS

The experience resulting from interacting with the IVIS has thus become an important focus of attention for designers of IVIS. *User experience* (UX) is defined in standard 9241-210 by the International Organization for Standardization (ISO, 2019) as a "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service". According to this definition, the experience of the users will be affected by a combination of aspects that pertain to the functioning and quality of the system (i.e., brand image, presentation, functionality, system performance, interactive behaviour, usability, and assistive capabilities) and subjective aspects (i.e., prior experience, attitudes, skills, and personality). In addition, the context of use will affect UX. The context of use consists of a combination of users, goals and tasks, resources and the environment (ISO, 2019). In the case of IVIS, the context of use consists of a combination of drivers and other car occupants, the

driving and infotainment goals and tasks, and different traffic scenarios, for example. All of these aspects will contribute to the overall UX resulting from the IVIS.

The distinction between aspects related to the functioning and quality of the system and subjective aspects is reflected in the model of UX by Hassenzahl (2018), who proposes that the quality of UX depends on both the pragmatic and hedonic quality of the product. According to Hassenzahl (2008b), *pragmatic quality* refers to the "product's perceived ability to support the achievement of *do-goals*" (p. 12). In other words, the pragmatic quality of the system relies on the extent to which the system supports the execution of the required tasks. *Hedonic quality* is the "perceived ability to support the achievement of *be-goals*" (p. 12) and relies on the extent to which a product supports its users in their basic needs for competence, autonomy, stimulation, popularity, and relatedness, for example. Hedonic quality can be further divided into the hedonic quality of stimulation and the hedonic quality of identification. The hedonic quality of stimulation refers to the extent to which the product supports the human needs for novelty and curiosity (Hassenzahl, 2008a). The hedonic quality of identification pertains to the human need for relatedness by communicating a good version of oneself to others (Hassenzahl, 2018). Altogether, the infotainment system should thus not only support the execution of infotainment tasks (i.e., pragmatic quality), but also support the user's needs (i.e., hedonic quality).

Pragmatic quality is strongly related to the usability of a product. *Usability*, as defined by the standards of the ISO 9241-210 (2019), is the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". With regard to IVIS, the system should support car occupants in executing the desired infotainment tasks effectively and efficiently, while taking into account the driving context. In addition, the usability of the system as perceived by the user should lead to satisfaction. The overall *satisfaction* of the end-user according to the ISO 9241-210 (2019) is affected by the *"*physical, cognitive and emotional responses that result from the use of a system*"* but also by the "anticipated use" and user's expectations. Satisfaction thus includes more subjective aspects of the experience related to the hedonic quality of a product. Usability and satisfaction are thus closely related to the pragmatic and hedonic quality of a system, respectively.

1.1.1. Designing for High-Quality UX

The goal of designers is to create infotainment systems that provide high-quality UX. Hassenzahl (2008b, p. 12) defines *good UX* as *"*the consequence of fulfilling the human needs

for autonomy, competency, stimulation (self-oriented), relatedness, and popularity (others-oriented) through interacting with the product or service (i.e., hedonic quality). Pragmatic quality facilitates the potential fulfilment of be-goals". According to this definition, the hedonic quality of the system, resulting from the fulfilment of human needs, directly contributes to the core of positive UX. The pragmatic quality of the system is required to make sure that the desired tasks can be executed, but only indirectly contributes to positive UX. In the end, the overall user satisfaction results from the extent to which the users are supported in achieving both their pragmatic and hedonic goals (Bevan, 2008). So, to design for high-quality UX of the infotainment system, the system should support the execution of the desired infotainment-related tasks, whilst also supporting the user's needs (e.g., for stimulation and relatedness).

Designers of infotainment systems should thus take into account the more emotional and aesthetic aspects regarding user satisfaction, as well as aspects regarding the effectiveness and efficiency of the system. To do so, the standards by ISO 9241-210 (2019) propose seven principles to take into account when designing interactive systems, these are the following:

1. Suitability for the task: this implies that the system should fit the task at hand. In the context of IVIS, this means that the design of the system should support the driver and other car occupants in performing their information and entertainment related tasks, whilst taking into account the safety of interaction in the driving context;
2. Self-descriptiveness: it should be clear to the user which actions can be taken and how this can be done. For the IVIS, this means that the system should be intuitive to use and clearly show what functionalities are accessible during driving;
3. Conformity with user expectations: the system should live up to the user's expectations. Related to IVIS, the system should work similarly to other IVIS or technologies that the user has interacted with before;
4. Suitability for learning: the user should be able to learn to operate the system quickly. This is important for IVIS, because if the system is easily learned, interaction will be less demanding, leading to less distraction from the primary driving task;
5. Controllability: the user should always be in control of the interaction. For IVIS, this means that the user should always be able to pause or cancel the interaction when they have to focus on the primary driving task, for example;
6. Error tolerance: the system should be able to deal with errors made by the user. Especially in the case of IVIS, users can hit the wrong buttons due to the motion in the vehicle. Users should be able to undo this easily;

7. Suitability for individualization: the system should provide the opportunity for users to adapt to their preferences. In the domain of IVIS, adapting the system can for example be done by making frequently used functionalities easily accessible (i.e., creating shortcuts).

These principles are mainly focused on task-oriented aspects of the system that contribute to the usability of the system. This makes sense, as the quality of interaction (i.e., usability) can be considered the core of UX (Borsci et al., 2019). The system has to be usable (i.e., allow the user to reach their goals) in order to result in positive experiences. When a system does not support the user in achieving their tasks, it is unlikely to result in a positive experience. However, the overall experience resulting from interaction with a system depends on aspects beyond usability. Therefore, UX takes a more holistic view of the human-system interaction by emphasizing the subjective and positive components of the experience (Bargas-Avila & Hornbæk, 2011; Petrie & Bevan, 2009).

It is important to take these subjective aspects into account when designing the system since users nowadays do not only want the system to help them execute the required tasks but also to be entertained and amused by the system (Petrie & Bevan, 2009). Unfortunately, guidelines on how to enhance the hedonic quality of a design appear to be scarce. Moreover, guidelines on how to design for luxury UX are even more limited. Nevertheless, Şener and colleagues (2016) propose four luxury values that might contribute to a luxurious experience. These will be discussed in the next section.

1.2. UX in the Context of Luxury IVIS

Luxury products are typically associated with excellent quality, expensiveness, superfluousness, exclusivity, prestigiousness, aesthetic beauty, and other emotional and symbolic associations (Laureiro & Kaufmann, 2016; Tynan et al., 2010). This suggests that luxury is mostly associated with hedonic quality aspects (Şener, 2019). Nevertheless, excellent functioning of luxury products is expected and therefore pragmatic quality aspects should also be considered in the context of luxury products. According to Şener and colleagues (2016), the luxuriousness of a product can be defined by four main dimensions, so-called luxury values, namely: (i) financial value, (ii) functional value, (iii) symbolic value, and (iv) experiential value. These values provide important insights regarding the elements of UX that are important to consider when designing luxury infotainment systems and will be discussed below.

Financial value is directly linked to the price of the product (Şener, 2019). A high price can be seen as an indicator of luxury (Vigneron & Johnson, 2004). Luxurious products are often made of more expensive, but also more durable materials, making them more costly. For infotainment systems, this suggests that the system should be made with durable materials such as metals and glass instead of plastics to enhance the luxuriousness of the system. In addition, the use of exclusive and cutting-edge technological solutions can enhance the financial value of luxury infotainment systems. Moreover, investing money in research to improve the design of the IVIS will also make the system more expensive, enhancing the financial value. Conversely, higher financial value will result in more resources to improve the system. This demonstrates the interconnectedness of the luxury values, enhanced financial value may enhance the other luxury values and vice versa.

Functional value refers to the functional attributes of the product, such as reliability, usability and durability (Şener, 2019). This value corresponds closely to the pragmatic quality of the system as proposed by Hassenzahl (2018): luxury products should help the user to reach their task-related goals. In addition, consumers of luxury products expect perfect functioning and service during use and expect the quality of the product to be superior to non-luxury products (Vigneron & Johnson, 2004). Therefore, Loureiro and Kaufmann (2016) suggest that luxury cars should go beyond the "bare necessities" and exceed the functionality of regular cars in order to reach desirability. The infotainment systems of luxury cars should thus also be functionally and technically superior to those found in regular cars.

Symbolic value can be described as the meaning attached to luxury products through experiences (Şener et al., 2016; Şener, 2019). This consists of both the meaning constructed by the brand itself, as well as the socially built meaning that will be associated with consumers of the luxury products (i.e., wealth and prestige). The symbolic value of a product is closely related to the hedonic quality of identification (Sen & Sener, 2020). In other words, luxury consumers want these products to support their needs for relatedness and popularity, for example by presenting their wealth and prestige to others. This makes sense, as the consumption of luxury products is often associated with self-representation (Yeoman & McMahon-Beattie, 2011). Consumers may perceive luxury products as an extension to the self and use these products to create their identity or to present their wealth and prestige to others (Vigneron & Johnson, 2004). The infotainment system of a luxury car should thus convey the user's social status to relevant others, as well as reinforce the owner's self-image.

Experiential value pertains to the individual interpretations of luxury through personal experience with the product (Şener et al, 2016; Şener, 2019). The experiential value of the

product depends on the extent to which the product will lead to individual satisfaction. This is very subjective and depends on the values, cultural background and personal aspirations of the consumer (Şener, 2019). Different consumers might value different qualities of the product. The experiential value of a product is closely related to hedonic quality aspects, especially the hedonic quality of stimulation (Sen & Sener, 2020). In general, people are stimulated by a product that appears to be interesting, novel, and exciting (Hassenzahl, 2018). Consumers of luxury products want the consumption of these products to be rewarding and fulfilling, using the product should be intrinsically pleasing (Vigneron and Johnson, 2004). The infotainment system should thus support the user in fulfilling their basic needs (e.g., autonomy, competence, stimulation) in order to result in individual satisfaction.

Altogether, the luxury values appear to be closely related to the hedonic and pragmatic qualities as proposed by Hassenzahl (2018), suggesting that these dimensions of UX are also important to consider in the context of luxury infotainment systems. The pragmatic quality of the system appears to be most important to consider when evaluating the quality of UX of luxury IVIS, since ill-functioning products cannot provide luxury (Şener et al., 2016). Although hedonic quality aspects are important contributors to the perceived luxuriousness of the system, they can only enhance perceptions of luxury as long as the pragmatic quality is established. In other words, the validity of symbolic and experiential values of the system thus depends on the functional value (Şener et al., 2016).

This dependence also indicates that all luxury values are interconnected, changes regarding one value might affect other values as well (Şener et al., 2016). For example, using novel technologies in the infotainment system might result in high functional value (i.e., pragmatic quality), but also to higher experiential value (i.e., hedonic quality). This interconnectedness between all luxury values should be taken into consideration while designing the IVIS. In the end, all four luxury values and associated dimensions of UX contribute to the overall luxuriousness of the system.

Luxury brands can differ in the extent to which they emphasize a certain luxury value, depending on the core values of the brand (Şener et al., 2016). Some luxury brands might emphasize the prestigiousness of the product (i.e., symbolic value), whereas other brands might emphasize the excellent performance of their product (i.e., functional value). Depending on the values that are emphasized most by the brand, resources can be allocated to assess these aspects. When the symbolic value is considered very important by the brand, aspects regarding the hedonic quality of identification should be emphasized during the assessment of the system. When the functional value is considered more important, the main

focus of the assessment will be on the pragmatic quality of the system. The next section will discuss methods for the assessment of infotainment systems.

1.3. UX Assessment of IVIS

Assessing aspects regarding the perceived quality of interaction of IVIS throughout the design process is important. Assessment will allow designers to check whether the product meets the desired level of quality, discover potential areas for improvement, or compare the products with other products on the market (i.e., benchmarking) (Øvad et al., 2020). UX assessment should be done as early as possible since the user requirements should be understood from the beginning to result in high-quality UX (Rajeshkumar et al., 2013) and changes can be made more easily in this stage of development (Väänänen-Vainio-Mattila et al., 2008).

However, UX assessment at an early stage is difficult because the concept might not yet be tangible and is therefore hard to understand for participants. In addition, the experience resulting from actual interaction with the product is lacking and the product can often not be tested in the real context of use, resulting in an incomplete experience (Roto et al., 2009; Väänänen-Vainio-Mattila et al., 2008). Nevertheless, existing methods for early-stage assessment can provide an estimation of the UX without requiring the system to be implemented in a real car. Although the resulting experience might be incomplete, the results can still give valuable insights to improve the system. Methods that are suitable to assess the UX of IVIS at an early stage will be discussed below.

First of all, Yogasara and colleagues (2011) proposed Anticipated User eXperience (AUX) to assess the UX of interactive systems at an early stage. In their study, they asked pairs of participants to imagine an interactive product and report their anticipated interactions and experiences with it. This type of assessment does not need a working prototype and can provide the designers with relevant ideas to enhance the UX of the system at an early stage. Yogasara and colleagues (2011) do emphasize the importance of using this data complementary to the results obtained from actual use, which might be especially important in the driving context where the safety of interaction has to be taken into account. Nevertheless, this could be a useful method to explore the UX of IVIS at an early stage.

In addition to the AUX method proposed by Yogasara and colleagues (2011), Roto and colleagues (2009) propose two other methods for the early assessment of the UX of interactive systems. First of all, they suggest expert evaluation using heuristics. As experts might have a better understanding of the raw concept, they should be able to provide feedback

on the preliminary concept before user studies. Second of all, online qualitative assessment of an early-stage concept is suggested. The early concept can be presented as a scenario that describes the system in its context of use, using media files that include text, images and audio (Roto et al., 2009). This way, minimum effort is required to ask a broad range of potential users about their thoughts on the early concept. Like AUX, these methods do not require a very advanced prototype nor do they require a lot of resources. Therefore, these methods appear to be suited to assess the UX of IVIS at a very early stage of the design process.

At later stages of the design process, where a (virtual) prototype of the system can be presented, the experience with the system can be simulated with the help of technology. Computers can be used to let users interact with a prototype of the system, or driving simulators that mimic real driving scenarios can be used to simulate interaction with the system. These driving simulators can provide realistic experiences with the system under controlled circumstances (Alvarez et al., 2015). The use of simulators can thus provide a realistic estimation of the UX of a system before it is implemented in a real car. As Wei and colleagues (2016) suggest, the simulation of UX thus plays an important role at the early stages of the design process.

Altogether, there are different ways to provide an estimation of the UX at an early stage. Tools are needed to measure the quality of this experience. The literature review by Bargas-Avila and Hornbæk (2011) showed that researchers apply a wide range of methods to assess UX (e.g., questionnaires, interviews, user observation, videorecording, focus groups, diaries, visualizations, body movement, and psychophysiological measures such as eye-tracking). These methods were used to assess the following dimensions of UX: generic UX, affect and emotion, enjoyment, aesthetics, hedonic quality, engagement/flow, motivation, enchantment, and frustration. There are thus many different ways to assess a variety of aspects regarding the UX of a system. As shown by Bargas-Avila and Hornbæk (2011), questionnaires are the most commonly used tools for assessing the quality of UX. The next section will discuss questionnaires as a tool to assess the UX of IVIS.

1.3.1. Standardized Questionnaires for UX assessment

Multiple standardized questionnaires for assessing (aspects regarding) the quality of UX exist. Standardized questionnaires are a popular tool for assessing UX, they can be filled out by the users themselves after interacting with the product, and are thus economical and easy to use (Díaz-Oreiro et al., 2019). Standardized questionnaires are questionnaires for

which there is an established procedure for using the tool and the reliability and validity are established by psychometric qualification (Lewis, 2016). The use of standardized questionnaires is thus not only convenient but also leads to reliable and valid measures of UX. According to the literature review performed by Díaz-Oreiro and colleagues (2019), the AttrakDiff, User Experience Questionnaire (UEQ), and modular evaluation of key Components of User Experience (meCUE) are the most recognized questionnaires for UX assessment. These three questionnaires will be discussed below.

First of all, the AttrakDiff questionnaire can be used to assess UX. The AttrakDiff assesses the hedonic and pragmatic quality aspects of UX as identified by Hassenzahl (2018) in addition to the overall attractiveness of the system. The questionnaire consists of 21 items for assessing hedonic and pragmatic quality and seven additional items for overall attractiveness (Hassenzahl et al., 2003). These items assess UX using a seven-point semantic differential scale. For example, users are asked to indicate to what extent they consider the system *simple* versus *complicated* (pragmatic quality), or *conservative* versus *innovative* (hedonic quality). The Cronbach's alpha for all subscales of the questionnaire is higher than .7, suggesting that there is good internal consistency. The questionnaire also has good construct validity, as suggested by the low intercorrelations between scales (Hassenzahl et al., 2003). This suggests that the AttrakDiff is a valid tool for measuring UX.

The second most used questionnaire for assessing UX is the UEQ. The UEQ also uses a semantic differential scale to assess UX. The UEQ consists of 26 items divided over six factors, namely; attractiveness, dependability, perspicuity, stimulation, efficiency, and novelty (Laugwitz et al., 2008). The Cronbach alpha of the UEQ exceeded the threshold of .7 for all subscales except dependability. This suggests that the overall reliability of this questionnaire is high. In addition, the subscales perspicuity, efficiency and dependability are correlated to the pragmatic quality scale from the AttrakDiff. The subscales novelty and stimulation are highly correlated with the stimulation scale from the AttrakDiff, and the subscale dependability is highly correlated with the identity scale of the AttrakDiff. These results suggest good construct validity and reliability of the UEQ (Laugwitz et al., 2008), indicating that the UEQ is a valid and reliable assessment tool for measuring UX.

Lastly, the meCUE can be used to measure the quality of UX. The meCUE questionnaire was created in an attempt to get a more complete assessment of the UX of a system, including aspects regarding emotions and consequences of usage (Minge et al., 2017). The items of this questionnaire consist of statements combined with seven-point Likert scales for users to indicate their agreement. The questionnaire consists of four modules: product

perceptions, user emotions, consequences of usage, and overall evaluation. For the module product perceptions, factor analysis resulted in five scales that were named the following: usefulness, usability, visual aesthetics, status, and commitment. The Cronbach's alpha was measured for each scale and suggest acceptable to excellent internal consistency, with all values exceeding .7. The scales also correlated highly with related scales from the AttrakDiff and UEQ. For example, visual aesthetics correlated highly with the stimulation and attractiveness dimensions of the AttrakDiff and the UEQ. All the modules and items were validated separately, the results suggest that meCUE would be a valid tool for assessing UX.

Taken together, the discussed questionnaires for assessing UX include aspects regarding both the pragmatic and the hedonic quality of the system, as well as an overall evaluation of the attractiveness of the system resulting from all aspects combined. The meCUE goes beyond this by also including aspects regarding the emotional response elicited in the user and the consequences of usage. All three questionnaires appear to be valid and reliable tools for assessing UX. However, it must be noted that these questionnaires are focused on UX in general and do not necessarily focus on UX in the context of luxury infotainment systems. Therefore, more research is needed to identify which dimensions of UX are especially important to consider in the context of luxury infotainment systems and how these can be assessed.

1.4. Aim of the Thesis

The aim of this thesis is to build a framework for the early-stage assessment of luxury IVIS that includes relevant dimensions of UX to consider during the assessment of luxury IVIS and tools for assessment. Designing infotainment systems that result in high-quality UX has become an important focus of attention for designers. However, it is unclear what aspects of UX are especially important to consider in the context of luxury IVIS and although methods for the evaluation of UX at early stages are available, little is known about their suitability in the context of luxury IVIS. Therefore, designers of infotainment systems would benefit from a framework for the early-stage assessment of luxury IVIS.

The need for such a framework is recognised by designers at ART, a company that is involved in designing and manufacturing infotainment systems for luxury cars. In collaboration with ART, this thesis will explore the relevant dimensions for evaluating the quality of UX for luxury infotainment systems and associated methods of assessment. Based on these dimensions of UX and methods of assessment a framework for the early-stage assessment of infotainment systems for luxury cars will be proposed. This framework will

help to explore potential solutions to the technical and interactive problems that are encountered during the design and provide tools to directly assess their effect on UX. Moreover, it will help designers to make decisions regarding the allocation of resources, find possible areas for improvement, evaluate changes, ensure that they are on the right track, compare with other products, or assess whether the final product meets the targets (Øvad et al., 2020; Vermeeren et al., 2010).

In order to build this framework, two phases are envisaged. In the first phase, a systematic literature review will be conducted to identify relevant aspects contributing to the UX of IVIS and accompanying methods to assess these. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) methodology as suggested by Liberati and colleagues (2009) was used to report the systematic review. Since specific literature on luxury IVIS is scarce, this review will include literature assessing the UX of both luxury and non-luxury IVIS, as well as the UX of luxury products in general. Based on the results of the literature review, a preliminary framework for the assessment of luxury infotainment systems will be proposed.

In the second phase of the research, the preliminary framework will be reviewed using a survey. Different stakeholders (i.e., designers, consumers of regular cars, and consumers of luxury cars) will be asked to indicate their agreement with the potential dimensions extrapolated from the literature and the relative importance of these dimensions. The results of this survey will be used to build a model of UX for IVIS for all groups of stakeholders. These models will be compared and discussed. Consequently, the preliminary framework will be amended according to the results. In the end, the resulting framework will be discussed as a tool to check design requirements and ensure the incorporation of key elements of UX at an early stage of product development, as well as a tool to guide the evaluation at later stages of design in terms of formative and summative assessment.

2. PHASE 1. METHODS OF THE LITERATURE REVIEW

2.1. Study Design

This systematic review was performed on journal articles examining the UX resulting from IVIS, as well as articles examining the UX of luxury products. Because there have been major developments in this field in the last years, this review only included articles published in the past 10 years.

2.2. Research Questions

To investigate what aspects of UX might be important for the assessment of infotainment systems for luxury vehicles and what methods can be used to assess these, the review aimed to answer the following research questions:

- RQ1: What are the key aspects assessed by researchers when evaluating the quality of UX of an IVIS?
- RQ2: Are the key aspects to assess when evaluating the quality of UX for regular IVIS the same for luxury IVIS?
- RQ3: Which standardized tools of assessment can be used to assess these key aspects for evaluating the quality of UX of IVIS?

2.3. Eligibility Criteria

For the literature on the UX of infotainment systems, records were included in the review if:

1. both aspects of UX or satisfaction and infotainment systems for vehicles were mentioned in the title, abstract, keywords, or main text.
2. the paper assessed aspects regarding the UX of IVIS and reported the methods used.

Records were excluded from the review if:

1. aspects of UX or satisfaction related to IVIS were not assessed in the study.
2. only technical aspects of infotainment systems were discussed.

Records on the UX assessment of luxury products were included if:

1. both aspects of UX and luxury products were mentioned in the title, abstract, keywords, or main text.
2. aspects regarding the UX of the product and associated methods of assessment were discussed.

Records were excluded if:

1. aspects regarding the assessment of UX of luxury products were not discussed in the paper.
2. the product evaluated was not a luxury product.

2.4. Search Strategy

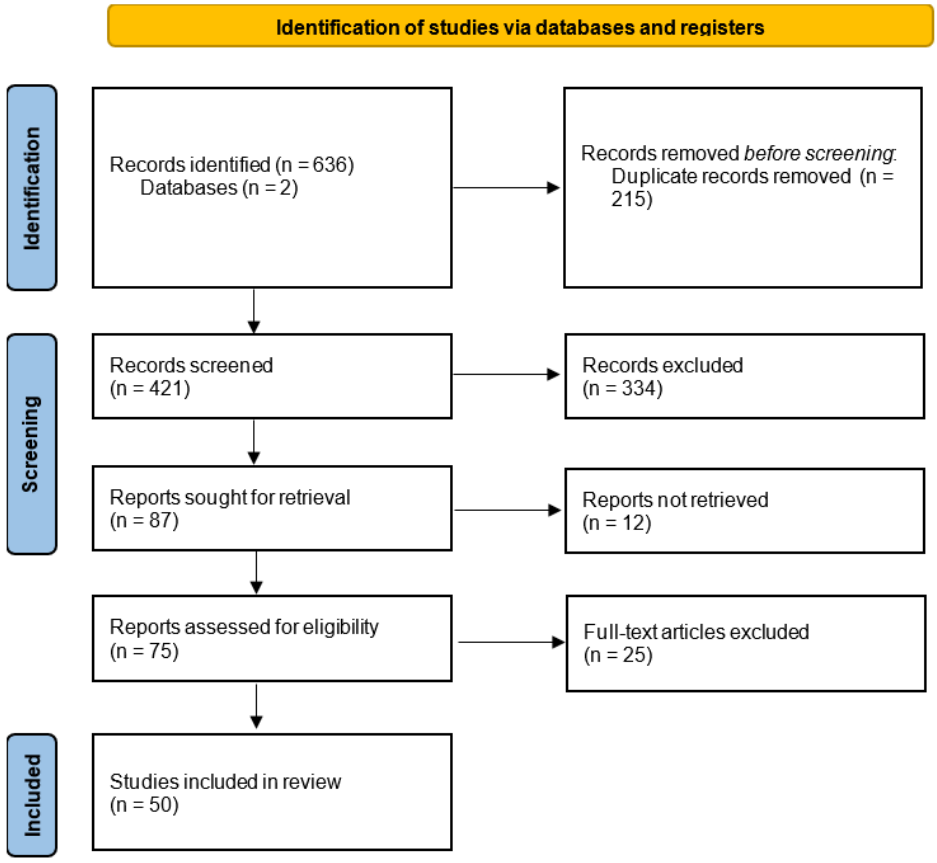
The records were retrieved from the databases Scopus and Web of Science combining the following keywords using the Boolean operators (AND/OR): user experience, UX, user interface, UI, user satisfaction, infotainment, vehicle, car, and luxury. Only articles written in English that were published in 2011 or later were included in the search.

3. RESULTS OF LITERATURE REVIEW

As shown in Figure 1, a total of 421 individual records were retrieved from Scopus and Web of Science. Articles either assessed aspects regarding the UX of IVIS or the UX of luxury products. Titles and abstracts of these articles were screened to see whether they complied with the inclusion and exclusion criteria. After screening, 334 records were excluded. The remaining 87 records were sought for retrieval. Twelve of these records were not accessible to the author and thus excluded from the analysis. The full text of the remaining 75 articles was then scanned. Twenty-five records were excluded from the analysis, either because they did not discuss the assessment of UX, or, for articles on luxury products, because the product evaluated was not a luxury product. In total, 50 articles were included.

Figure 1

Flowchart depicting the Review Process in Accordance with the PRISMA guidelines (Liberati et al., 2009)



These 50 articles were read and systematized to identify relevant aspects and methodologies for assessing the quality of UX of IVIS. Table 1 provides an overview of the studies included in the review, listing their domain of application, study objectives, aspects of UX that were assessed, and the methods applied by the researchers.

Table 1

Summary Overview of Reviewed Articles

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
1. Jung et al. (2021)	Automotive	Compare the quality of interaction of different designs	*familiarity, learnability, intuition, and overall usability*	Driving experience questionnaire
			perception of momentary confusion	Reduced Clutter Score (RCS)
			perceived workload	NASA-TLX
2. Čegovnik et al. (2020)	Automotive	Compare the quality of interaction of different designs	*attractiveness, perspicuity, efficiency, dependability, stimulation and novelty*	UEQ
			perceived workload	NASA-TLX
			workload	Pupil dilation
3. Young et al. (2020)	Automotive	Compare the quality of interaction of different designs	*perceived usability*	User Acceptance Testing
			first impressions and expectations	Verbal questions

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
			reliability, intuitiveness, and ease-of-use	Interviews
4. Khan et al (2020)	Automotive	Evaluate the quality of interaction of a design	*perceived usability*	System Usability Scale (SUS)
			intention to use, attitude, ease-of-use, cognitive load, visual engagement, physical engagement, user satisfaction, augmenting memory, and improving driving behavior	Quantitative questions
5. Berger et al (2019)	Automotive	Compare the quality of interaction of different designs	*perceived usability*	SUS
			attractiveness, hedonic qualities, and pragmatic quality	AttrakDiff questionnaire
			subjective aspects of the concept	Semi-structured interview

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
6. Frison et al. (2019)	Automotive	Compare the quality of interaction of different designs (in different situations)	*attractiveness, hedonic qualities, and pragmatic quality*	AttrakDiff mini
			autonomy, competence, stimulation, and security	Need scale
			emotions	PANAS
			trust	Trust scale and Galvanic Skin Response
7. Galarza & Paradells (2019)	Automotive	Evaluate the quality of interaction of a design	*desirability, convenience, and more (not reported)*	Questionnaire on opinion and perceived benefits
8. Biondi et al. (2019)	Automotive	Compare the quality of interaction of different designs	*perceived workload*	NASA-TLX
			intuitiveness and complexity	Quantitative questions
			perceived usability	SUS

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
			sentiment/polarity of the experience	Verbal comments
9. Kula et al. (2017)	Automotive	Compare the perceived quality of different designs	*visual attention, engagement, emotional arousal, drowsiness, and fatigue*	Eye-tracking
			cognitive workload, engagement, distraction, and drowsiness	EEG
			emotional valence and engagement	Automated facial expression analysis
10. Lux et al. (2018)	Automotive	Compare the quality of interaction of different designs	*perceived usability*	SUS
			attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty	UEQ
			perceived workload	NASA-TLX
			overall experience and impressions	Structured interview

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
			intuitiveness	Quantitative questions
11. Ingi Árnason et al (2014)	Automotive	Evaluate the quality of interaction of a design	*extent to which the system is safe, annoying, intelligent, dangerous, good, or average*	Quantitative questions
			general impression	Comments
12. Farooq et al. (2014)	Automotive	Compare the quality of interaction of different designs	*pleasantness and arousal*	Quantitative questions
			to assess *user perspectives*	Product Reaction Card approach
			overall system	Interviews
13. Broy et al. (2012)	Automotive	Compare the quality of interaction of different designs	*workload and distraction*	Peripheral Detection Task
			attractiveness, hedonic qualities, and pragmatic quality	Subset of AttrakDiff
			ease of perceiving	Quantitative question

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
			perceived workload	Rating Scale Mental Effort (RSME)
14. Charissis et al. (2021)	Automotive	Compare the quality of interaction of different designs	*perceived usability*	Quantitative questionnaire User feedback
15. Kim and Yoo (2021)	Automotive	Compare the quality of interaction of different designs	*attractiveness, hedonic qualities, and pragmatic quality*	AttrakDiff
16. Park & Im (2020)	Automotive	Compare the quality of interaction of different designs	*perceived workload*	Modified Cooper-Harper handling scale (MCH)
17. Prabhakar et al. (2020)	Automotive	Compare the quality of interaction of different designs	*perceived workload* *perceived usability*	NASA-TLX SUS
18. Kim et al. (2020)	Automotive	Compare the quality of interaction of different designs	*perceived workload* *perceived usability*	NASA-TLX SUS Interviews
19. Caon et al. (2020)	Automotive	Evaluate the quality of interaction of a design	*perceived usability* *experience and general feedback*	SUS Qualitative questions

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
20. Wang et al. (2019)	Automotive	Evaluate the quality of interaction of a design	*the extent to which the system is attractive, entertaining, capturing attention, and distracting*	Qualitative questions
21. Jung et al. (2019)	Automotive	Compare the quality of interaction of different designs	*perceived usefulness, perceived ease-of-use, behavioural intention, attitude, and global evaluation*	Quantitative questionnaire
22. Grogna et al. (2018)	Automotive	Compare the quality of interaction of different designs	(*perceived) workload* *personal experience*	NASA-TLX EEG Undefined questionnaire
23. Jang et al. (2017)	Automotive	Evaluate the quality of interaction of a design	*intuitive awareness, behaviour change and psychological effect of perceived infotainment*	Undefined survey In-depth interviews
24. Sterkenburg et al. (2017)	Automotive	Compare the quality of interaction of different designs	*perceived workload*	NASA-TLX
25. Buchhop et al. (2017)	Automotive	Compare the quality of interaction of different designs	*perceived workload* *perceived distraction, security, and confidence, intentions to use*	NASA-TLX Qualitative questionnaire

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
26. Shakeri et al. (2017)	Automotive	Compare the quality of interaction of different designs	*perceived workload* *preferences*	NASA-TLX Qualitative questionnaire
27. Feng et al. (2017)	Automotive	Compare the quality of interaction of different designs (and use the results to develop a computer-aided engineering software toolkit for designing IVIS to predict and benchmark the system usability)	*perceived workload*	NASA-TLX
28. Wang et al. (2017)	Automotive	Evaluate the quality of interaction of a design	*interestingness, enjoyment, difficulty, physical demand*	Quantitative questionnaire
29. Angelini et al. (2016)	Automotive	Compare the quality of interaction of different designs	*perceived workload* *perceived usability* *emotions*	Driving Activity Load Index (DALI) SUS PANAVA-KS
30. May et al. (2016)	Automotive	Compare the quality of interaction of different designs	*perceived workload*	NASA-TLX

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
31. Winkler et al. (2016)	Automotive	Compare the quality of interaction of different designs	*intuitiveness*	Questionnaire for Intuitive Use (QUESI)
			innovativeness and challengingness	Hedonic quality – stimulation scale from AttrakDiff
			perceived workload	SEA-Skala (German translation of Subjective Mental Effort Questionnaire *SMEQ*)
			familiarity	10-point scale
32. Reichel et al. (2015)	Automotive	Compare the quality of interaction of different designs	*likability, annoyance, and system response accuracy*	Adapted Subjective Assessment of Speech System Interfaces (SASSI) questionnaire
			help, concentration, and overall impression	Questionnaire for subjective quality evaluation of telephone services based on spoken dialogue systems (ITU-T Rec. P.851)

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
33. Chen et al. (2015)	Automotive	Compare the quality of interaction of different designs	*irritation, perceived effect on driving performance, perceived usefulness* *subjective satisfaction*	(Semi-open) Questionnaires Likert scale
34. May et al. (2014)	Automotive	Compare the quality of interaction of different designs	*perceived workload*	NASA-TLX
35. Lauber et al. (2014)	Automotive	Compare the quality of interaction of different designs	*perceived usability* *perceived workload* *readability, occlusion, level of subjective distraction*	SUS NASA-RTLX Quantitative questions
36. Parada-Loira et al. (2014)	Automotive	Compare the quality of interaction of different designs	*reliability, perceived security for driving, subjective distraction, usefulness, ease of use, necessity, desirability, willingness to pay for it*	Quantitative questionnaire

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
37. Macek et al. (2013)	Automotive	Compare the quality of interaction of different designs	*perceived usability*	SUS
			system response accuracy, likeability, cognitive demand, annoyance, habitability, speed	Subjective Assessment of Speech System Interfaces (SASSI)
			perceived workload	DALI
38. Pfleging et al. (2012)	Automotive	Compare the quality of interaction of different designs	*perceived usability*	SUS
			perceived workload	DALI
39. Pakkanen et al. (2012)	Automotive	Compare the quality of interaction of different designs	*perceived performance, pleasantness, difficulty, demand, simplicity, expected u*se	Quantitative questionnaire
40. Garzon (2012)	Automotive	Compare the quality of interaction of different designs	*perceived workload*	NASA-TLX
			attractiveness, hedonic qualities, and pragmatic quality	AttrakDiff

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
41. Pitts et al. (2012)	Automotive	Compare the quality of interaction of different designs	*user preference, hedonic rating, confidence, difficulty, interference with driving, strength and realism of haptic stimulus*	Quantitative questionnaire after driving
			preferences, pleasure and ease-of-use	Quantitative follow-up questionnaire
42. Döring et al. (2011)	Automotive	Compare the quality of interaction of different designs	*likeability, perceived distraction, ease-of-use*	Quantitative questionnaire
Articles on UX of luxury products				
43. Berger et al. (2021)	Luxury automotive	Evaluate the quality of interaction of a design	*attractiveness, hedonic qualities, and pragmatic quality*	AttrakDiff
			self-explanatory	Qualitative questions
			perceived usefulness and perceived future use	Semi-structured interviews

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
44. Sen & Sener (2020)	Luxury automotive	Evaluate the quality of interaction of a design	*pragmatic and hedonic qualities and luxury aspects* *overall experience and suggestions*	Adapted AttrakDiff Follow-up interview
45. Coudounaris (2018)	Luxury automotive	Compare the evaluation of a luxury brand by users and non-users of the product and their country of origin	*innovativeness, attractiveness, prestige, craft/workmanship, appeal, likeability, uniqueness, and originality*	Online quantitative questionnaire
46. Qi & Jang (2021)	Luxury online shopping	Compare the quality of interaction of different designs	*satisfaction, trust, interactive experience, usage efficiency, rationality of information, clarity of guidance, freedom of transaction, and overall evaluation*	Quantitative questions
47. Øvad et al. (2020)	Luxury audio devices	Develop framework for assessing UX key performance indicators (for luxury audio products)	*interaction, differentiating experience, comfortableness, polish*	Self-made scales based on SUS, UEQ, AttrakDiff

Authors	Domain	Objectives of the study	Aspects of UX assessed	Methods of assessment
48. Ramadan (2019)	Luxury online shopping	Evaluate the expected adoption of a product delivering luxury service	*perceived risk, personal experience, and functional and relational value*	Elite interviewing
49. Altarteer et al. (2017)	Luxury online shopping	Evaluate the quality of interaction of a design	*visibility of system status; match between system and real world; user control and freedom; consistency and standards; error prevention; recognition rather than recall; flexibility and efficiency of use; aesthetic and minimalist design; sense of presence; compatibility with task and domain; natural engagement*	Heuristic evaluation
50. Morillo et al. (2019)	Luxury online shopping	Compare the quality of interaction of different designs	*fun of experience, ergonomics, interaction, satisfaction, suitability, difficulty, and usefulness* *system preference and whether they would recommend*	Self-made quantitative questionnaire Additional questions

3.1. Potentially Relevant Dimensions of UX for Infotainment Systems

The aspects and associated methods of assessment used in the studies as listed in Table 1 were analysed qualitatively. The aspects that were assessed most frequently by the researchers were listed and these aspects were grouped together with similar or related aspects. For example, aspects like intuitiveness, efficiency, and simplicity were clustered together into the dimension of perceived usability. This qualitative analysis resulted in six overarching dimensions of UX that appear to be important in the context of IVIS, as follows:

1. *Perceived usability:* This dimension refers to the extent to which the system supports the user in executing the desired infotainment tasks and is closely related to the pragmatic quality of the system. The dimension of perceived usability emerged from all the studies that refer to the assessment of perceived usability, pragmatic quality, and ease-of-use using questionnaires such as the System Usability Scale (SUS), Questionnaire for Intuitive Use (QUESI), or the pragmatic quality subscales of the AttrakDiff and UEQ. These questionnaires include items regarding, for instance, intuitiveness, efficiency, effectiveness, learnability, predictability, simplicity etc. Other studies that assessed similar aspects were also clustered into the dimension of perceived usability.
2. *Cognitive workload and distraction:* This dimension refers to the extent to which interacting with the system is cognitively demanding in terms of workload, attention and distraction. This dimension was based on studies that refer to the assessment of cognitive workload using the NASA Task Load Index (NASA-TLX) or similar questionnaires assessing workload, such as the Driving Activity Load Index (DALI). These questionnaires assess aspects related to the demands of the system and the effort required for interaction. Studies that assessed similar aspects regarding distraction and the mental demand of the system, such as level of attention and concentration, were also clustered into this dimension.
3. *Overall attractiveness:* This dimension emerged from all the studies that discuss an overall evaluation of the product or system resulting from all aspects combined. For example, the combination of intuitive, beautiful, and innovative design elements results in an overall likeable system. The attractiveness subscales of the AttrakDiff and the UEQ assess the overall attractiveness by measuring aspects such as pleasantness, attractiveness, goodness, appeal, and likeability. Other studies assessing these and similar aspects were also clustered into this dimension.

4. *Stimulation and innovation:* This dimension is closely related to the hedonic quality of stimulation and pertains to the extent to which the system supports the human need for novelty and curiosity (Hassenzahl, 2008a). This dimension was based on all studies that refer to the assessment of the hedonic quality of stimulation, using the hedonic quality of stimulation scale of the AttrakDiff or the hedonic quality scales of the UEQ, for example. These questionnaires include items to assess the extent to which the system is perceived as exciting, innovative, creative, novel, or challenging etc. Studies that assessed these and similar aspects were also clustered into this dimension.
5. *Prestige and exclusivity:* This dimension is closely related to the hedonic quality of identification and pertains to the extent to which the system aids in communicating a good version of oneself to relevant others (Hassenzahl, 2008a). The dimension of prestige and exclusivity emerged from all studies that refer to the assessment of the hedonic quality of identification, such as done by the hedonic quality of identification scale of the AttrakDiff. This subscale of the AttrakDiff includes items that assess the extent to which the system is perceived as stylish, professional, or integrating, for example. Studies that assessed related aspects, such as aesthetics, prestige, uniqueness, exclusiveness, professionality, and connectedness etc. were also clustered into this dimension.
6. *Positive affiliation:* This dimension pertains to the extent to which interaction with the system results in positive responses in terms of emotions, perceptions, feelings and opinions. This dimension evolved from studies that discussed the assessment of aspects pertaining to the emotions resulting from interaction with the system or product, such as done by using physiological measurements or questionnaires such as the Positive and Negative Affect Schedule (PANAS) or the Positive Activation Negative Activation Valence Scale (PANAVA-KS). These questionnaires assess the extent to which the system results in positive or negative emotions, using items measuring the extent to which the user is interested, irritable, inspired, happy, etc. Studies that assess similar or related aspects are also clustered into this dimension.

These six dimensions identified from literature can be seen as potentially relevant dimensions of UX for assessing the quality of infotainment systems. Appendix A shows for each record which dimensions were assessed. Table 2 proposes an overview of the potential dimensions, the underlying aspects assessed in the literature that the dimension is based on, and the standardized tools used to assess these aspects.

Table 2

Overview of Potential Dimensions, Underlying Aspects Assessed in Literature, and Standardized Tools used for Assessment

Potential dimension	**Description**	**Underlying aspects**	**Standardized tools**
Perceived usability	The extent to which the system supports the user in executing the desired infotainment tasks	Pragmatic quality, intuitiveness, ease-of-use, efficiency, effectiveness, learnability, predictability, simplicity	SUS QUESI AttrakDiff *(pragmatic quality subscale)* UEQ *(efficiency, perspicuity, and dependability subscales*) SASSI
Cognitive workload and distraction	The extent to which interacting with the system is cognitively demanding in terms of cognitive workload, attention and distraction	Cognitive workload, concentration, distraction, attention	NASA-TLX DALI RSME Subjective Mental Effort Questionnaire (*SMEQ*) MCH SASSI
Overall attractiveness	The overall attractiveness of the system resulting from all aspects combined, often expressed in terms of goodness, likeability, or attractiveness	Attractiveness, desirability, global evaluation, pleasantness, enjoyment, likeability	AttrakDiff (*attractiveness subscale)* UEQ (*attractiveness subscale)* SASSI

Stimulation and innovation	The extent to which the system supports the human need for novelty and curiosity	Hedonic quality of stimulation, entertaining, innovative, novel, challenging	AttrakDiff (*hedonic quality of stimulation subscale)* UEQ *(stimulation and novelty subscales)*
Prestige and exclusivity	The extent to which the system supports communicating a good version of oneself to others	Hedonic quality of identification, aesthetics, prestige, uniqueness, exclusiveness, professional, integrating	AttrakDiff *(hedonic quality of identification subscale)*
Positive affiliation	The extent to which interaction with the system results in positive responses in terms of emotions, perceptions, feelings and opinions	Emotions, attitude, annoyance	PANAS PANAVA-KS SASSI

3.2. Frequency of Assessment of Potential Dimensions

The potential dimensions of UX for IVIS differ in the extent to which they are assessed in the literature. Table 3 presents the frequency of assessment of the potential dimensions and distinguishes between the literature on IVIS and literature on luxury products. In general, more pragmatic quality aspects such as perceived usability and cognitive workload and distraction are most frequently assessed, suggesting that these dimensions are most important to evaluate. These dimensions are followed by more hedonic quality aspects, such as overall attractiveness, stimulation and innovation, and prestige and exclusivity. More emotional aspects as represented by the dimension of positive affiliation are assessed least, suggesting that these are least important to evaluate during the assessment of UX of infotainment systems.

Differences regarding the frequency of assessment of the dimensions can be observed for the different types of products assessed in the literature. In literature evaluating the UX of infotainment systems, aspects regarding cognitive workload and distraction were assessed most frequently, whereas this dimension has not been assessed in the literature on luxury products. Similarly, aspects regarding positive affiliation were not assessed in studies on luxury products. Moreover, perceived usability, stimulation and innovation, and prestige and exclusivity were assessed relatively more in the literature on luxury compared to studies on infotainment systems.

Table 3

Frequency of Assessment of Potential Dimensions of UX in the Reviewed Literature

Type of literature reviewed	**Total**		**UX of IVIS**		**UX of luxury products**	
Potential dimension	**N**	**%***	**N**	**%***	**N**	**%***
Perceived usability	33	66	26	61	7	88
Cognitive workload and distraction	30	60	30	71		
Overall attractiveness	21	42	18	43	3	38
Stimulation and innovation	18	36	13	30	5	62
Prestige and exclusivity	14	28	8	19	6	75
Positive affiliation	9	18	9	21		

Note. N = 50 studies * does not sum up to 100% because studies can measure multiple aspects.

3.3. Methods used to Assess Potential Dimensions of UX

Different methods to assess the potential dimensions of UX were used in the literature. For each potential dimension, the standardized tools used in the literature are listed in Table 2. Table 4 provides an overview of these standardized tools used in the literature, together with their frequency of use and the potential dimensions that can be assessed by this questionnaire. The NASA-TLX, used to assess aspects regarding cognitive workload and distraction, was used most (n = 14). After that, the SUS, used to assess perceived usability, was used most frequently (n = 12). The third most used questionnaire is the AttrakDiff (n = 9), this questionnaire can be used to assess aspects regarding multiple dimensions of UX, similarly to the UEQ that was used by four of the studies included. In addition to these standardized tools, self-made questionnaires and interviews were often used to assess aspects of UX. Furthermore, physiological measurements were used. For example, Kula and colleagues (2017) used EEG to assess cognitive workload and distraction.

Table 4

Frequency of Use of Standardized Tools

Standardized Tool	Frequency	Potential Dimension
NASA-TLX	14	Cognitive workload and distraction
SUS	12[a]	Perceived usability
UEQ	3[a]	Perceived usability, stimulation and innovation, overall attractiveness
DALI	3	Cognitive workload and distraction
SASSI	2[a]	Cognitive workload and distraction, perceived usability, overall attractiveness, positive affiliation
PANAS	1	Positive affiliation
PANAVA-KS	1	Positive affiliation
MCH	1	Cognitive workload and distraction
SMEQ	1	Cognitive workload and distraction
RSME	1	Cognitive workload and distraction

[a] includes adapted versions of questionnaire.

4. INSIGHTS FROM THE LITERATURE REVIEW

The first aim of this literature review was to identify key aspects to consider when evaluating the quality of UX of IVIS. The results suggest that there are six potential dimensions to consider, namely: *perceived usability*, *cognitive workload and distraction, overall attractiveness, stimulation and innovation, prestige and exclusivity,* and *positive affiliation*. These potential dimensions and associated methods of assessment have been introduced in the previous section. The results of the literature review showed that aspects regarding cognitive workload and distraction and the perceived usability of the system were assessed most, whereas aspects regarding the positive affiliation were assessed least. This suggests that aspects concerning the perceived usability and cognitive workload and distraction of the system are more important to consider than aspects concerning the positive affiliation and other hedonic quality aspects when evaluating the quality of UX of IVIS.

This emphasis on perceived usability and cognitive workload and distraction makes sense because these aspects are strongly related to the pragmatic quality and (perceived) safety of the system. In order to maintain safe roads, the infotainment system should be easy to use, so that it does not require too much workload and attention and does not distract the driver from the road. Moreover, Song (2020) suggests that perceived safety is one of the most important contributors to the UX of IVIS. In addition, the pragmatic quality of the system needs to be established before more hedonic quality aspects can enhance the quality of UX (Hassenzahl, 2008b; Şener, 2019) Altogether, it is sensible to put most resources into the assessment of aspects regarding the perceived usability as well as the cognitive workload and distraction of the system. It must be noted, that the previously mentioned dimensions are mainly based on literature assessing the quality of UX for regular IVIS. Therefore, it is necessary to further explore the significance of these dimensions in the context of luxury infotainment systems.

4.1. Potential Dimensions of UX in the Context of Luxury IVIS

The second aim of the literature review was to establish whether the identified dimensions of UX that are relevant for infotainment systems of standard model commercial cars are also important to consider when evaluating luxury infotainment systems. Only eight studies assessed aspects regarding the quality of UX resulting from interaction with luxury products (see Table 3). These studies suggest that perceived usability, prestige and exclusivity, stimulation and innovation, and overall attractiveness are also important for assessing the UX of IVIS in a luxury context. This makes sense if you take a look at how

these dimensions correspond to the luxury values defined by Şener and colleagues (2016). Perceived usability is strongly related to the functional value of the system. Aspects regarding prestige and exclusivity are related to the symbolic value of the system. Similarly, aspects regarding stimulation and innovation are strongly related to the experiential value. Overall attractiveness is related to the overall luxury value since both cover the overall evaluation of the system. The compatibility between these dimensions and the luxury values suggests that these dimensions of UX are indeed important to consider in the context of luxury IVIS.

The results of the literature review thus indicate that researchers mainly focus on pragmatic and hedonic quality aspects associated with the luxury values while evaluating the quality of UX of luxury products. The emphasis on these aspects makes sense, as this will help to establish the functional superiority expected of luxury products (Vigneron & Johnson, 2004) and enhance the overall luxuriousness of the system (Şener, 2019). Researchers seem to have chosen to focus on aspects associated with luxury without considering aspects specific to the cognitive demand of the system. The latter is reflected by the lack of assessment regarding aspects concerning cognitive workload and distraction in the reviewed literature on the UX of luxury products. These findings imply that this dimension is not important to consider in the context of luxury products in general. However, many of the studies on luxury products were in other domains than the automotive field and might therefore not have assessed aspects regarding cognitive workload and distraction. As suggested by Song (2020) perceived driving safety is one of the most important contributors to the UX of IVIS. Therefore, aspects regarding cognitive workload and distraction should also be considered in the context of luxury IVIS.

The results of the literature review also suggest that aspects regarding positive affiliation do not seem to be important to consider in the context of luxury products, as indicated by the lack of assessment of this dimension in articles on luxury products. This finding is surprising, since emotions appear to be one of the most frequently assessed dimensions of UX (Bargas-Avila & Hornbæk, 2011) and emotional value seems to be important when considering the purchase of luxury products (Lim et al., 2012). The lack of assessment of aspects regarding positive affiliation might be due to the low sample of studies on UX of luxury products and their different domains of application. Nevertheless, assessing these emotional responses can give valuable insights into the quality of UX of luxury IVIS, as the emotional value of the system is an important contributor to the overall luxury value of the system (Lim et al., 2012).

Overall, the potential dimensions of UX extrapolated from the literature on general IVIS thus seem to include the aspects usually studied when it comes to luxury products and even go beyond this by including aspects regarding cognitive workload and distraction, and positive affiliation. However, there appears to be a difference in the extent to which the different dimensions are emphasized in the context of luxury products compared to regular IVIS. As can be seen in Table 3, aspects regarding prestige and exclusivity, and stimulation and innovation are assessed relatively more in the studies on the UX of luxury products compared to studies on the UX of regular IVIS. These results suggest that there might be an increased emphasis on dimensions related to the hedonic quality of UX in the context of luxury IVIS.

The increased emphasis on hedonic quality aspects in the context of luxury IVIS makes sense, as the consumption of luxury products is often associated with more hedonic quality aspects (Şener, 2019). Studies asking people about the perceived luxuriousness of IVIS found that aspects regarding the symbolic and experiential value of the system were mentioned most (Sen and Sener, 2020; Şener, 2019). These results suggest that although the functional value of the system is required (i.e., the system should function properly), the symbolic and experiential value of the system will further enhance perceptions of luxury. In addition, consumers generally have higher expectations regarding the quality of luxury products (Vigneron & Johnson, 2004). The quality of luxury infotainment systems is expected to exceed that of regular systems, suggesting that all dimensions of UX should be emphasized more in the context of luxury IVIS. Designers should thus make sure that infotainment systems live up to the expectations of luxury consumers. To do so, the use of appropriate tools for assessing the quality of the system is required.

4.2. Methods of Assessment

The third aim of the literature review was to identify the most commonly used tools that can be used to assess the quality of UX. A wide range of methods for UX assessment is available (Bargas-Avila & Hornbæk, 2011). Only two of the reviewed studies used physiological measures to assess aspects like attention, trust, or emotional responses (Frison et al., 2019; Kula et al., 2017). These methods allow the evaluation of UX in a more direct and objective way during interaction with the system (Kula et al., 2017). However, this type of assessment usually requires more resources and a working prototype. Therefore, it is questionable to what extent it is useful for UX assessment at early stages. More research on

using these methods (at early stages of assessment) is needed, but is beyond the scope of this thesis.

Almost all studies included in the review (96%) assessed aspects regarding the quality of UX using interviews or questionnaires. These questionnaires were either standardized questionnaires such as the AttrakDiff or UEQ, or self-made questionnaires. Although self-made questionnaires might seem informative, it is hard to compare results with other studies, or to replicate results. Instead, standardized tools could offer more comparable and reusable results by facilitating researchers and practitioners to communicate the results, generalize their findings, and replicate results (Nunnally, as cited in Lewis, 2016). Moreover, using standardized tools will increase the objectivity of the results (Nunnally, as cited in Lewis, 2016) and allow for benchmarking and comparison with other systems (Schrepp et al., 2017). An overview of the standardized tools used in the reviewed literature can be found in Table 4. These tools could be useful to assess the potential dimensions of UX of IVIS at an early stage. In the remainder of this section, the potential of standardized tools for assessing the UX of luxury IVIS will be discussed.

The standardized tool used most frequently in the reviewed literature is the NASA-TLX. This tool was used to assess aspects regarding cognitive workload and distraction. The NASA-TLX consists of the following six subscales to assess the perceived workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. In addition to the NASA-TLX, a few studies used the DALI to assess perceived workload. The DALI is a revised version of the NASA-TLX, especially adapted to the driving task (Pauzié, 2008). The DALI assesses the following six dimensions of workload: effort of attention, visual demand, auditory demand, temporal demand, interference, and situational stress. According to Pauzié (2008) the DALI offers the possibility to identify the origins of the driver's workload, making it easier to adapt the system accordingly. Therefore, the DALI might be better suited for the assessment of cognitive workload in the context of (luxury) IVIS.

The second most used standardized tool was the SUS. This tool is intended to measure the perceived usability of the system by asking respondents to indicate their agreement with statements about the system. Half of the statements have a positive tone, whereas the other half have a negative tone. Although the psychometric properties of the SUS are overall good, some inconsistencies have been observed regarding its construct validity (Lewis et al., 2015). Even though the scale is intended to be unidimensional, there are indications that the SUS might be bidimensional in some situations. Borsci and colleagues (2015) found that the SUS appears to be bidimensional when administered to more experienced users. However, when

administered after a short period of use, the scale does appear to be unidimensional. This suggests that for early-stage assessment of IVIS, where experience with the system is not likely to be extensive, the SUS could be a useful tool for assessing perceived usability.

The AttrakDiff was the third most frequently used standardized tool found in the reviewed literature. The AttrakDiff can be used to assess multiple aspects of UX and is quite similar to the UEQ. Both questionnaires assess aspects regarding perceived usability, overall attractiveness, and stimulation and innovation using slightly different semantic differentials. The main difference between these questionnaires seems to be that the AttrakDiff includes a subscale for the hedonic quality of identification, which can be used to assess aspects regarding prestige and exclusivity, whereas the UEQ does not seem to include any items regarding this dimension. The finding that the AttrakDiff was used most in the reviewed literature is in line with the results of the literature review by Díaz-Oreiro and colleagues (2019), who also found that AttrakDiff was used most to evaluate UX. They explained this finding by the fact that the AttrakDiff was the first questionnaire to be introduced. Interestingly, the results of their review also showed that the UEQ is now surpassing the AttrakDiff questionnaire in its number of uses. This suggests that the assessment of IVIS might also benefit from using the UEQ more in the future.

In addition to the questionnaires found in the literature, other validated questionnaires can be used to assess the key aspects of UX for IVIS. Positive affiliation, for example, was not often assessed by standardized tools in the reviewed literature. Only one study used the PANAS to assess emotions (Frison et al., 2019), and one study used the PANAVA-KS to assess emotional responses (Angelini et al., 2016). Although these might be suitable questionnaires for assessing emotions, other established and validated methods for assessing emotional responses are available and should be considered (Bargas-Avila & Hornbæk, 2011). One example could be the third module of the meCUE. The meCUE, in general, could be a suitable questionnaire for assessing these and other key aspects regarding the UX of IVIS. The review by Díaz-Oreiro and colleagues (2019) showed an increase in use of the meCUE in the past years, suggesting that this questionnaire may be valuable for the assessment of luxury infotainment systems in the future. More research is needed to explore the potential of the meCUE and other standardized tools that have not been used in the reviewed literature.

Researchers also suggest complementing the standardized scales with interviews to obtain valuable insights regarding the UX of IVIS, especially at an early stage. Interviews will allow researchers to get the rationale behind answers and expose problems or generate ideas

that would otherwise not be considered. For example, Bach and colleagues (2011) showed that interviews provided a more detailed understanding of the emotional experience and helped to understand the shift between emotional responses and the subjective assessment of usability. Therefore, conducting interviews or applying other methods to assess UX can be a valuable addition to standardized tools.

In sum, (combinations of) standardized tools and interviews could be used to assess the potential dimensions of UX for (luxury) infotainment systems at an early stage. The choice for a particular questionnaire, or particular items, may depend on the aspects that are emphasized by the brand values and the resources available. Combining (sub)scales will allow for a broad range of aspects to be assessed. For example, using the AttrakDiff in combination with the DALI and the PANAS will roughly cover all aspects. Additionally, the SUS can be added to this set to get a better idea of the perceived usability, or the QUESI can be added to further assess the intuitiveness of the system. Novel questionnaires like the meCUE should also be considered to assess the UX of IVIS at early stages.

4.3. Initial Framework based on Literature Review

Overall, six potential dimensions regarding the UX of infotainment systems were extrapolated from the literature. These six dimensions seem to be important to consider in the context of luxury IVIS as well. However, expectations regarding the quality of the experience appear to be generally higher and hedonic quality aspects seem to be emphasized more in the context of luxury infotainment systems compared to regular infotainment systems. To assess the quality of UX of (luxury) IVIS, the use of standardized tools is recommended. Items or subscales from multiple standardized tools can be combined to assess a broad range of aspects. What questionnaires to use depends on the resources available and the specific aspects of UX that are emphasized by the brand values.

Based on the findings from the literature review, a preliminary framework for the assessment of UX of IVIS can be drafted. Table 5 shows the six potential dimensions for assessing UX and potentially suitable standardized tools that can be used for assessment. The aspects are ordered based on the frequency of assessment in the literature (i.e., implied importance), with perceived usability, implied to be most important, first, and positive affiliation, implied to be least important, last. For each dimension, the most-used standardized tools in the reviewed literature and the most promising novel standardized tools for assessment are indicated.

Table 5

Preliminary Framework for Assessing the UX of Luxury Infotainment Systems

Potential dimension	Standardized tool for assessment
1. Perceived usability	• SUS • QUESI • AttrakDiff • UEQ • SASSI • meCUE
2. Cognitive workload and distraction	• DALI • NASA-TLX • SASSI
3. Overall attractiveness	• AttrakDiff • UEQ • SASSI • meCUE
4. Stimulation and innovation	• AttrakDiff • UEQ
5. Prestige and exclusivity	• AttrakDiff • meCUE
6. Positive affiliation	• PANAS • PANAVA-KS • SASSI • meCUE

4.4. Further Validation of Framework

As the identified dimensions are mainly based on the literature analysis on UX of IVIS in general (i.e., both luxury and non-luxury cars), the next phase of this research will try to validate this framework in the context of both luxury and regular cars' infotainment systems. To do so, a survey will be spread to get the opinion of designers of infotainment systems as well as consumers of both luxury and regular cars on the importance of the potential dimensions extrapolated from literature. The survey will aim to achieve consensus on the identified dimensions of UX as well as establish the relative importance of these dimensions.

The survey data can be used to explore whether the mental models of designers are in line with the mental models of consumers. Mental models are representations of reality that help people understand the world around them, understanding these mental models can help improve the quality of UX (Filippi & Barattin, 2017; Filippi & Barattin, 2018; Villareale & Zhu, 2021). In the context of interactive systems, interaction-related mental models are mental models that are focused on the interaction with a system and help users understand the interface of the system. These mental models consist of meanings and emotions and the accompanying actions of the user and reactions of the system (Filippi & Barattin, 2017). Exploring the mental models of users will benefit the design process by helping designers to understand consumers' needs and preferences and apply this knowledge to create positive experiences (Filippi & Barattin, 2017; Hsu et al., 2000). To explore the differences between mental models of designers and consumers of both luxury and regular cars, these three types of respondents will be distinguished from each other.

Based on the results of the literature review, differences between the mental models of designers, luxury car consumers, and regular car consumers can be expected. For example, aspects regarding prestige and exclusivity might be more important to consider in the context of luxury IVIS, as indicated by the relatively higher frequency of assessment of this dimension in the context of luxury products. This could suggest that consumers of luxury cars might value prestige and exclusivity more compared to consumers of regular cars. Consumers of luxury cars might thus differ from consumers of regular cars in the extent to which they value the different dimensions of UX, resulting in differences between the mental models of these two types of consumers. Moreover, Hsu and colleagues (2000) suggest that designers might value different aspects of UX compared to consumers. In other words, the mental models of designers might differ from consumers as well. Therefore, the survey will explore the potential differences between the mental models of these actors when it comes to establishing what is considered important when assessing the UX with IVIS.

5. PHASE 2. METHODS OF SURVEY STUDY

5.1. Survey Design

An online survey was developed to establish consensus on the importance of the six potential dimensions for assessing the UX of IVIS derived from literature and to explore the relative importance of these dimensions. Since differences between the mental models of luxury car consumers, regular car consumers, and designers of infotainment systems are of interest, these three types of respondents were distinguished from each other. The survey was adjusted slightly to each type of respondent, resulting in three versions of the survey (see Appendix B). The survey was made available in four languages; English, Italian, Dutch, and German, and enabled us to reach anonymous respondents throughout Europe. The study received full ethics approval from the University of Twente ethical committee.

Each version of the survey started with a demographic section. After this, the respondent was presented with the survey adjusted to either regular car consumers, luxury car consumers, or designers of infotainment systems. First, the survey inquired the respondent's agreement level with the six potential dimensions proposed based on the literature review. The dimensions were introduced in a simplified manner and respondents were asked to what extent they agreed that this dimension is important to consider. After that, pairwise comparisons on all dimensions were performed. Respondents were asked to indicate the dimension they considered to be more important for every pair of dimensions. The dimensions and their descriptions were presented on top of the page to make it easier for participants to compare the dimensions. The order of the agreement and comparison questions was randomized. At the end of the survey, respondents were provided space to comment and suggest more potentially important aspects.

5.2. Survey Distribution

Before the survey was distributed, the survey was piloted among five acquaintances of the researcher to review the clarity and coherence of the survey and check for any mistakes or other obstacles disturbing the flow of interaction. The necessary adjustments were made before the survey was distributed to a broader public.

The survey was shared on social media (Facebook, LinkedIn) to reach a broad audience. As most of this audience fell in the group of regular car consumers, specific groups on luxury cars were targeted to reach consumers of luxury cars. In addition, groups of people working in the automotive sector were targeted to reach designers of infotainment systems. Moreover, people working on the (design of) infotainment systems were invited to fill out the

survey via Facebook, LinkedIn, or email. Lastly, luxury car dealers were approached to fill out the survey and distribute it among their customers. The advertisements on social media and the messages sent included an invitation to the survey, a description of the study objectives, the expected time to complete the survey, and a link to the survey itself.

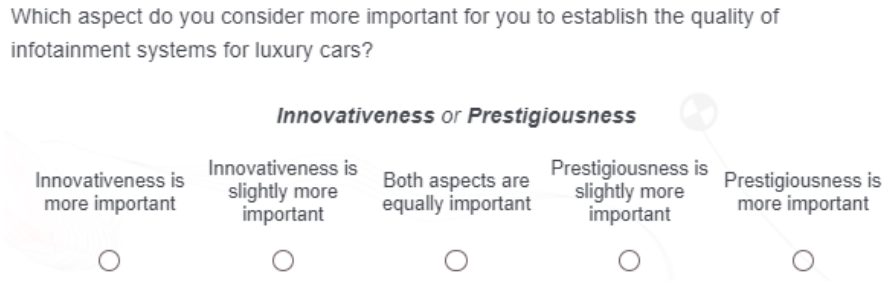
5.3. Measurements and Analysis

To measure the agreement with the potential dimensions, a 7-point Likert scale was applied, where "1" indicated strongly disagree and "7" indicated strongly agree. The median scores were calculated for each dimension, this indicates the answer category above and below which 50 percent of the answers fall. In addition, the interquartile ranges (IQRs) were calculated to see the spread of the data and the level of consensus, with smaller IQRs representing more consensus (Polisena et al., 2018). In this type of analysis if a potential dimension is rated with a median ≤ 3 and a narrow IQR (i.e., IQR range ≤ 2), this dimension is considered to have reached a consensus disagreement (i.e., the dimensions is not important). Dimensions that are rated with a median ≥ 5 and a narrow IQR are considered to have reached a consensus agreement (i.e., the dimension is important). This analysis was done on the aggregated data of all respondents, as well as the data of the three groups of respondents separately.

To assess the relative importance of the potential dimensions, respondents were asked to indicate for each pair of potential dimensions which one they considered more important on a 5-point scale. See Figure 2 for an example of a comparison question. The *bpcs* (Bayesian Paired Comparisons in Stan) package in R was used to analyse the data. This package facilitates the use of Bayesian models, such as the Bradley-Terry model, to analyse paired comparisons (Issa Mattos & Martins Silva Ramos, 2021). Because respondents to our survey were allowed to indicate they considered two dimensions equally important, the Davidson model was used as an extension to handle the so-called 'ties' between dimensions (Issa Mattos & Martins Silva Ramos, 2021). To account for the fact that each respondent made multiple comparisons, which can be considered dependent on each other, the respondents were added as a random effect. The different tools in the *bpcs* package were used to derive the lambda parameters (indicating the priority of the dimension) with 95% Highest Posterior Density (HPD) intervals for each dimension per group, as well as the mean and median ranks, and the probabilities of one dimension being considered more important than another.

Figure 2

Example of Pairwise Comparison Question in the Survey



Lastly, the comments of the participants at the end of the survey were reviewed as these can provide insights regarding potentially important aspects or dimensions that might be missing from the proposed list.

6. RESULTS OF SURVEY STUDY

6.1. Demographics of Respondents

Of the 163 people that started the survey, 130 provided usable results. Sixteen respondents completed only the first part; 114 respondents completed the whole survey. Six different types of nationalities were represented in the survey, with the majority of the respondents being from Italy (*n* = 101; 76.9 %), followed by 24 respondents from the Netherlands (18.5 %), two respondents from Germany (1.5 %) and one respondent each from Ireland, Moldova, and Denmark. The age of the respondents ranged from 18 to 67 (M = 38, SD = 11.2). Most respondents specified their sex indicated at birth to be male (*n* = 93, 71.5 %), the remaining 28.5 percent specified as female (*n* = 37). The majority of the respondents were regular car consumers (*n* = 97; 75 %), over 10 percent of respondents were luxury car consumers (*n* = 16; 12 %), or designers of infotainment systems (*n* = 17; 13 %).

6.2. Consensus on Potential Dimensions

To analyse the consensus with the potential dimensions, the medians and IQRs were retrieved for each dimension per group. The results are presented in Table 6. The boxplots in Figure 3 show a visual representation of the results. All medians have a value equal to or higher than 5, suggesting that there is agreement for all dimensions. However, the IQR for prestige and exclusivity is not sufficiently narrow for the groups of regular and luxury car consumers to have reached a consensus on the importance of this dimension. The dimension of cognitive workload and distraction also has a wide IQR for luxury consumers, indicating lower consensus on this dimension for this group.

Table 6

Median and IQR for each Potential Dimension in Total and per Group

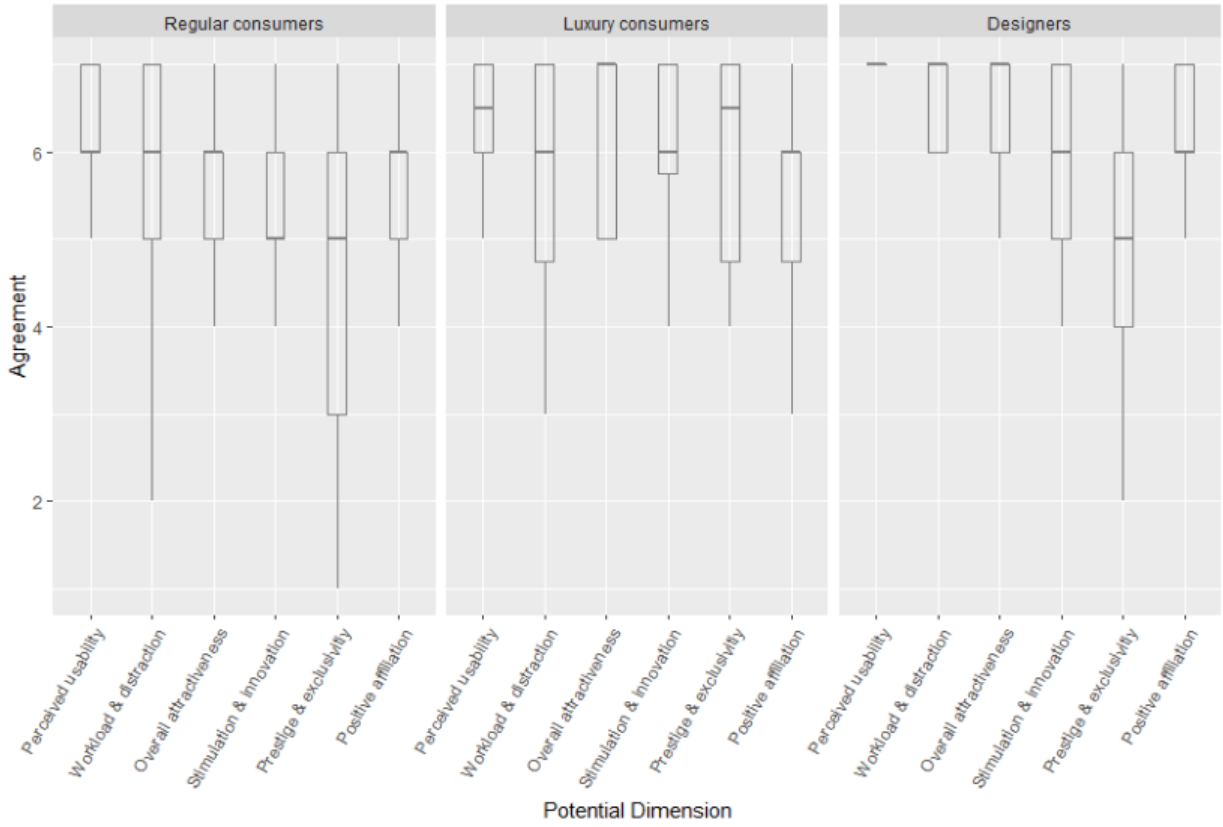
Group	**Total**	**Regular Consumers**	**Luxury Consumers**	**Designers**
	(N = 130)	**(*n* = 97)**	**(*n* = 16)**	**(*n* = 17)**
Potential Dimension	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**
Perceived usability	7 (5, 7)	6 (6, 7)	6.5 (6, 7)	7 (6, 7)
Cognitive workload and distraction	6 (5, 7)	6 (5, 7)	6 (4.75, 7) [a]	6 (5, 7)
Overall attractiveness	6	6	7	6

	(5, 7)	(5, 6)	(5, 7)	(5, 7)
Stimulation and innovation	6	5	6	6
	(5, 6)	(5, 6)	(5.75, 7)	(5, 6)
Prestige and exclusivity	5	5	6.5	5
	(4, 6)	(3, 6) [a]	(4.75, 7) [a]	(4, 6)
Positive affiliation	6	6	6	6
	(5, 6)	(5, 6)	(4.75, 6)	(5, 6)

[a] IQR > 2, indicating lower agreement

Figure 3

Boxplots Depicting Medians and IQRs of Potential Dimension per Group



6.3. Relative Importance of Potential Dimensions

The paired comparison data was analysed using the Davidson extension of the Bradley-Terry model to retrieve the relative importance of the potential dimensions. Based on the models, the priorities of each dimension, as well as the rankings of the dimensions and the probabilities of one dimension being considered more important than another can be obtained for each group of respondents (i.e., regular consumers, luxury consumers, and designers). The results will be presented below.

6.3.1. Priorities

Table 7 shows the obtained lambda parameters, representing the priority value, for each dimension together with the 95% HDP intervals to indicate credibility. The results are summarized per group. To visualize these results, Figure 4 shows a comparison of the estimates from the model for each group of respondents. Whereas the results of the groups of regular car consumers and designers clearly show differences regarding the priorities of the different dimensions (e.g., a high priority for perceived usability and low priority for prestige and exclusivity), the priorities for luxury car consumers do not seem to differ much, as represented by the overlapping confidence intervals.

The U1_std parameter represents the standard deviation in the random effects and the difference between subjects (Issa Mattos & Martins Silva Ramos, 2021). The results show that respondents within the group of designers differ the least from each other, whereas respondents in the group of luxury consumers differ most. The nu parameter indicates the probability of a tie, the nu parameters are close to zero, suggesting that the probability of a tie depends on the priorities of the dimensions.

Table 7

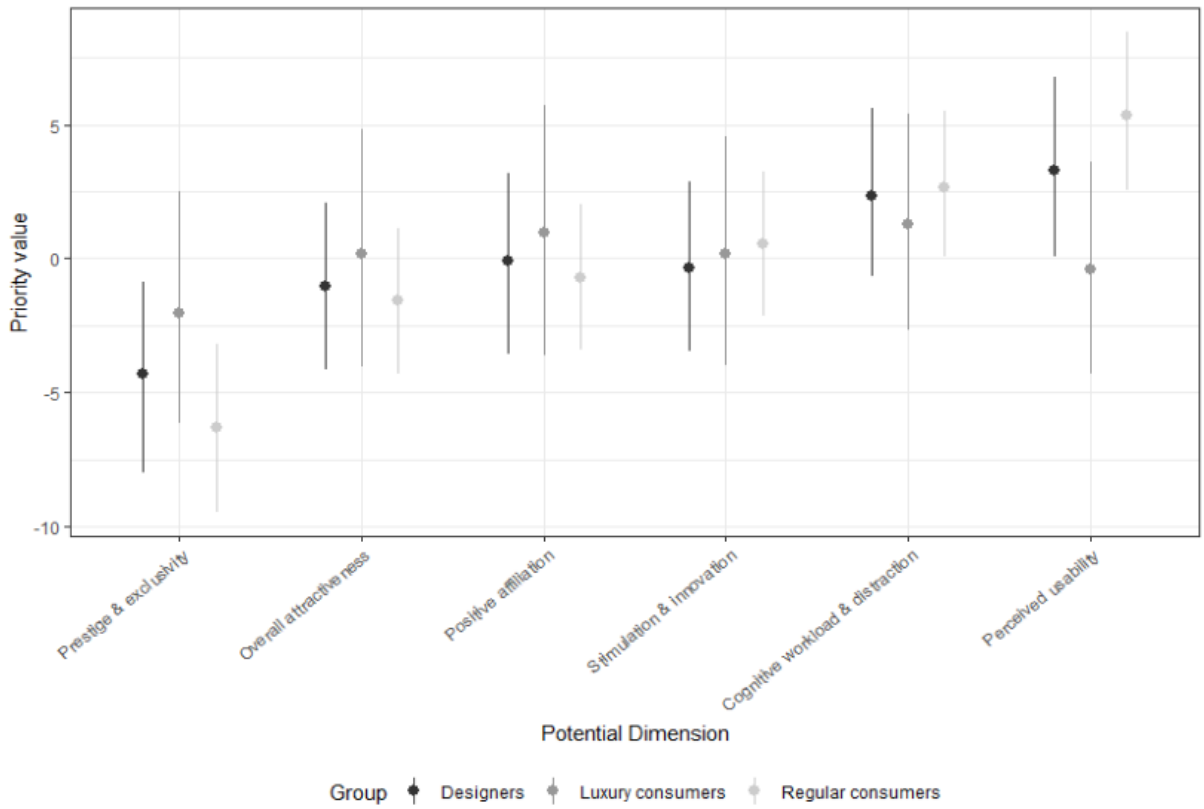
Parameters of the Random Effects Model with 95% HPD and Number of Effective Samples

Parameter	**Mean**	**Median**	**HPD lower**	**HPD upper**	**N. Eff. Samples**
Regular consumers (*n* = 88*)*					
Perceived usability	5.36	5.34	2.57	8.44	2764
Cognitive workload and distraction	2.68	2.68	0.06	5.50	2427
Overall attractiveness	-1.58	-1.56	-4.30	1.16	2268
Stimulation and innovation	0.56	0.56	-2.12	3.22	2362
Prestige and exclusivity	-6.32	-6.29	-9.45	-3.17	2248
Positive affiliation	-0.72	-0.73	-3.41	2.02	2337
U1_std	5.56	5.48	3.91	7.36	1664
nu	-0.70	-0.71	-1.26	-0.15	4548
Luxury consumers (*n* = 9*)*					
Perceived usability	-0.42	-0.40	-4.28	3.60	5554
Cognitive workload and distraction	1.27	1.28	-2.64	5.42	6505
Overall attractiveness	0.16	0.17	-4.03	4.82	5862
Stimulation and innovation	0.16	0.16	-3.99	4.55	5993

Prestige and exclusivity	-2.03	-2.07	-6.15	2.51	5679
Positive affiliation	0.96	0.95	-3.59	5.72	6253
U1_std	6.25	6.12	3.28	9.62	5222
nu	-0.02	-0.02	-0.59	0.56	8079
Designers (*n* = 16)					
Perceived usability	3.31	3.25	0.08	6.74	5592
Cognitive workload and distraction	2.34	2.32	-0.65	5.63	5357
Overall attractiveness	-1.04	-1.04	-4.16	2.09	4928
Stimulation and innovation	-0.36	-0.37	-3.46	2.85	5181
Prestige and exclusivity	-4.31	-4.22	-7.97	-0.85	4941
Positive affiliation	-0.10	-0.13	-3.55	3.20	4225
U1_std	4.17	4.04	2.29	6.44	3179
nu	-0.17	-0.16	-0.75	0.42	10948

Figure 4

Parameter Estimates with the 95% HPD Interval



6.3.2. Rankings

Table 8 shows the ranks of the potential dimensions for each group, the median, mean and standard deviations. The rank is calculated from the posterior distribution of the parameters in Table 7. Table 8 shows that regular consumers have a clear rank for perceived usability, cognitive workload and distraction, and prestige and exclusivity, given the low standard deviations of these ranks. For luxury consumers, the standard deviations of the ranks are relatively high, indicating that the rankings of luxury consumers are less consistent. For the designers, the ranks are somewhat clearer than for luxury consumers, but not as clear as the ranks for regular consumers. The resulting rankings for regular consumers and designers appear to be quite similar, indicating perceived usability and cognitive workload and distraction to be most important to consider, whereas prestige and exclusivity appear to be least important to consider. For luxury consumers, perceived usability is not regarded as one of the most important dimensions to consider, as reflected by the median rank of 4.

It is worth noting that this analysis is performed at the group level, not at the level of the individual respondents. This could suggest that within the group of luxury consumers, individual respondents might have clear rankings of the dimensions, however, these rankings might differ from each other to such an extent that there is no clear ranking at the group level.

Table 8

Estimated Posterior Ranks of Potential Dimensions per Group

Group	**Median Rank**	**Mean Rank**	**Std. Rank**
Regular consumers			
Perceived usability	1	1.00	0.00
Cognitive workload and distraction	2	2.01	0.09
Stimulation and innovation	3	3.10	0.34
Positive affiliation	4	4.11	0.54
Overall attractiveness	5	4.78	0.43
Prestige and exclusivity	6	6.00	0.00
Luxury consumers			
Cognitive workload and distraction	2	2.49	1.39
Overall attractiveness	3	3.34	1.59
Positive affiliation	3	2.82	1.61
Stimulation and innovation	3	3.41	1.56

Perceived usability	4	3.88	1.50
Prestige and exclusivity	6	5.05	1.30
Designers			
Perceived usability	1	1.31	0.53
Cognitive workload and distraction	2	1.84	0.62
Positive affiliation	4	3.63	0.91
Stimulation and innovation	4	3.83	0.86
Overall attractiveness	5	4.45	0.81
Prestige and exclusivity	6	5.94	0.26

6.3.3. Probabilities

In addition to rankings, the relative importance of the dimensions can be assessed by the posterior probability of prioritizing one dimension over the other. These probabilities are calculated over the averages of subjects per group. Table 9 shows the probabilities of one dimension being considered more important than another. These probabilities can also be expressed in terms of odds ratios, indicating how likely one dimension is to be considered more important than the other. As the respondents were allowed to indicate two dimensions equally important to consider, the probability of a tie is also given in Table 9. Tables 10, 11, and 12 represent the probabilities of one dimension being considered more important than another visually. Higher probabilities of one dimension being considered more important than another are marked green and lower probabilities are marked red. The greener the row belonging to a dimension, the more likely this dimension is to be considered more important than the other dimensions.

The results show that for regular consumers, the dimension of perceived usability is always more likely to be considered most important when compared to any other dimension. For example, there is a 67% chance that perceived usability will be considered more important than cognitive workload and distraction. Moreover, it is certain that perceived usability will be considered more important than prestige and exclusivity, as indicated by the probability of 1. Cognitive workload and distraction is also more likely to be considered most important when compared with any other dimension, except for perceived usability. In contrast, prestige and exclusivity is always less likely to be considered most important when compared with any other dimension.

Designers show a similar pattern to that of regular consumers, with enhanced probabilities of ties for the comparisons between stimulation and innovation, overall

attractiveness, and positive affiliation and the comparison between perceived usability and cognitive workload and distraction (as indicated in bold in Table 9). This suggests that designers are more likely to consider these dimensions equally important. For luxury consumers, the probabilities are less pronounced and the probabilities of a tie are relatively higher compared to regular consumers. This indicates that luxury consumers are more likely to consider two dimensions equally important.

Table 9

Posterior Probabilities of Relative Importance of Dimensions per Group

Dimension i	Dimension j	Prob. i beats j	Odds Ratio	Prob. of Tie
Regular consumers				
Perceived usability	Cognitive workload and distraction	**0.67**	2.03	0.10
Perceived usability	Overall attractiveness	**0.95**	19.00	0.02
Perceived usability	Stimulation and innovation	**0.88**	7.33	0.07
Perceived usability	Prestige and exclusivity	**1.00**	Inf	0.00
Perceived usability	Positive affiliation	**0.96**	24.00	0.01
Cognitive workload and distraction	Overall attractiveness	**0.86**	6.14	0.06
Cognitive workload and distraction	Stimulation and innovation	**0.71**	2.45	0.14
Cognitive workload and distraction	Prestige and exclusivity	**1.00**	Inf	0.00
Cognitive workload and distraction	Positive affiliation	**0.74**	2.85	0.13
Overall attractiveness	Stimulation and innovation	0.09	0.10	0.15
Overall attractiveness	Prestige and exclusivity	**0.91**	10.11	0.03
Overall attractiveness	Positive affiliation	0.26	0.35	0.19
Stimulation and innovation	Prestige and exclusivity	**0.95**	19.00	0.02
Stimulation and innovation	Positive affiliation	0.44	0.79	0.15
Prestige and exclusivity	Positive affiliation	**0.00**	0.00	0.03
Luxury consumers				
Perceived usability	Cognitive workload and distraction	0.14	0.16	0.29
Perceived usability	Overall attractiveness	0.21	0.27	0.21
Perceived usability	Stimulation and innovation	0.29	0.41	0.23
Perceived usability	Prestige and exclusivity	0.56	1.27	0.15
Perceived usability	Positive affiliation	0.27	0.37	0.29
Cognitive workload and distraction	Overall attractiveness	0.39	0.64	0.24

Cognitive workload and distraction	Stimulation and innovation	0.50	1.00	0.13
Cognitive workload and distraction	Prestige and exclusivity	0.72	2.57	0.17
Cognitive workload and distraction	Positive affiliation	0.34	0.52	0.23
Overall attractiveness	Stimulation and innovation	0.34	0.52	0.22
Overall attractiveness	Prestige and exclusivity	0.59	1.44	0.22
Overall attractiveness	Positive affiliation	0.29	0.41	0.22
Stimulation and innovation	Prestige and exclusivity	0.51	1.04	0.24
Stimulation and innovation	Positive affiliation	0.31	0.45	0.20
Prestige and exclusivity	Positive affiliation	0.13	0.15	0.21
Designers				
Perceived usability	Cognitive workload and distraction	0.37	0.59	**0.30**
Perceived usability	Overall attractiveness	0.79	3.76	0.11
Perceived usability	Stimulation and innovation	0.75	3.00	0.16
Perceived usability	Prestige and exclusivity	0.97	32.33	0.02
Perceived usability	Positive affiliation	0.72	2.57	0.06
Cognitive workload and distraction	Overall attractiveness	0.74	2.85	0.12
Cognitive workload and distraction	Stimulation and innovation	0.63	1.70	0.15
Cognitive workload and distraction	Prestige and exclusivity	0.92	11.50	0.04
Cognitive workload and distraction	Positive affiliation	0.54	1.17	0.19
Overall attractiveness	Stimulation and innovation	0.18	0.22	**0.28**
Overall attractiveness	Prestige and exclusivity	0.68	2.13	0.16
Overall attractiveness	Positive affiliation	0.15	0.18	**0.27**
Stimulation and innovation	Prestige and exclusivity	0.75	3.00	0.06
Stimulation and innovation	Positive affiliation	0.33	0.49	**0.28**
Prestige and exclusivity	Positive affiliation	0.04	0.04	0.11

Table 10

Posterior Probabilities of Regular Consumers

Prob. i beats j	Perceived usability	Cognitive workload and distraction	Overall attractiveness	Stimulation and innovation	Prestige and exclusivity	Positive affiliation
Perceived usability		0,67	0,95	0,88	1	0,96
Cognitive workload and distraction	0,23		0,86	0,71	1	0,74
Overall attractiveness	0,03	0,08		0,09	0,91	0,26
Stimulation and innovation	0,05	0,15	0,76		0,95	0,44
Prestige and exclusivity	0	0	0,06	0,03		0
Positive affiliation	0,03	0,13	0,55	0,47	0,97	

Dimension i / Dimension j

Table 11

Posterior Probabilities of Luxury Consumers

Prob. i beats j	Perceived usability	Cognitive workload and distraction	Overall attractiveness	Stimulation and innovation	Prestige and exclusivity	Positive affiliation
Perceived usability		0,14	0,21	0,29	0,56	0,27
Cognitive workload and distraction	0,57		0,39	0,5	0,72	0,34
Overall attractiveness	0,58	0,37		0,34	0,59	0,29
Stimulation and innovation	0,48	0,37	0,44		0,51	0,31
Prestige and exclusivity	0,29	0,11	0,19	0,25		0,13
Positive affiliation	0,44	0,43	0,49	0,49	0,66	

Dimension i / Dimension j

Table 12

Posterior Probabilities of Designers

	Prob. i beats j	Dimension j: Perceived usability	Cognitive workload and distraction	Overall attractiveness	Stimulation and innovation	Prestige and exclusivity	Positive affiliation
Dimension i	Perceived usability		0,37	0,79	0,75	0,97	0,72
	Cognitive workload and distraction	0,33		0,74	0,63	0,92	0,54
	Overall attractiveness	0,1	0,14		0,18	0,68	0,15
	Stimulation and innovation	0,09	0,22	0,54		0,75	0,33
	Prestige and exclusivity	0,01	0,04	0,16	0,19		0,04
	Positive affiliation	0,22	0,27	0,58	0,39	0,85	

6.4. Comments

At the end of the survey, participants were asked to comment on any other aspects they would consider important for the assessment of luxury infotainment systems that we missed to propose. The comments indicated that connectivity could be an important aspect to consider, consumers want their infotainment systems to be able to connect with their phones and other devices, for example by enabling Apple CarPlay or similar Android services. Other respondents mentioned the importance of the graphic design of the system, this could be closely related to visual aesthetics, but also the ease of use.

Aspects regarding usability were often mentioned in the comments. Specifically, respondents mentioned the response time and reactivity of the system to be important to consider. In addition, the importance of innovation was emphasized. For example, innovative types of interaction (i.e., gesture, voice, or eye-movement-based interaction) were mentioned. However, one of the respondents remarked that the haptic feedback resulting from physical buttons will reduce the distraction resulting from interacting with the system, suggesting more conventional types of interaction to be better in terms of cognitive workload and distraction.

7. DISCUSSION

The goal of this study was to identify and establish the importance of the potential dimensions of UX for infotainment systems and to assess the relative importance of these dimensions from the perspective of different stakeholders (e.g., designers and consumers). Based on the results, the initial framework for evaluating the quality of UX of infotainment systems proposed at the end of the literature review will be amended. The resulting framework will be discussed as a tool to guide the design as well as the early-stage evaluation of (luxury) infotainment systems. Consequently, the limitations of the research will be discussed and directions for further research will be provided.

7.1. Survey Results

7.1.1. Agreement with the Proposed Dimensions

Generally, all stakeholders agreed that the proposed dimensions were important to consider when evaluating the quality of infotainment systems. However, the results indicated that the importance of prestige and exclusivity was questioned by respondents in each group. Moreover, luxury consumers differed in the extent to which they considered the dimension of cognitive workload and distraction important. These findings will be discussed in more detail below.

The importance of the dimension prestige and exclusivity was questioned by consumers of regular cars. Almost half of the regular consumers (45%) did not agree that aspects regarding prestige and exclusivity are important to consider. The low level of agreement suggests that these aspects that are strongly related to social status are less relevant for consumers of regular cars. This seems in line with indications from Vigneron and Johnson (2004). They propose that seeking for the symbolic representation of status is particularly relevant in the process of acquiring and consuming luxury products. The large spread of the IQR in the data suggests that regular consumers differ in the extent to which they consider this dimension important. Whereas roughly half of the consumers of regular cars value the symbolic representation associated with the infotainment system, the other half does not. Thus, there does not seem to be a consensus on the importance of the dimension prestige and exclusivity for consumers of regular cars.

Regarding luxury consumers, the results of the survey showed that 75% of the luxury consumers agreed that aspects concerning prestige and exclusivity are important to consider. This suggests that prestige and exclusivity should be considered when assessing the quality of IVIS for luxury cars. However, the wide spread of the IQR for luxury consumers suggest that

there are differences within the group of luxury consumers regarding the extent to which they considered the dimension of prestige and exclusivity to be important. According to Campbell (2011), people that consume luxury products for social status often do not wish to admit this. Some of the respondents in this study might have been reluctant to admit that they consider this dimension to be important. This might explain the observed differences between respondents in this group. Nevertheless, the results suggest that aspects regarding prestige and exclusivity are generally considered important by the majority of luxury consumers.

Designers were asked to consider the importance of the dimensions in the context of luxury cars. The majority of the designers (65%) agreed that aspects regarding prestige and exclusivity are important to consider when designing infotainment systems for luxury cars. The spread of the IQR was sufficiently narrow, indicating that designers have interpreted this dimension more alike. However, designers seemed to agree with prestige and exclusivity to a lesser extent compared to the other dimensions, as indicated by the lower boundary of the IQR for this dimension (i.e., Q1 = 4). This suggests that designers did not consider this dimension as essential to the quality of UX as the other dimensions proposed. The symbolic value related to prestige and exclusivity is often created by the representation of the brand or constructed by society (Sener, 2016). In this sense, the perceived prestige and exclusivity of the system depend on aspects beyond the design of the system itself. Designers might thus have less control over this dimension and therefore regard aspects regarding prestige and exclusivity as less important to consider when designing an infotainment system.

The dimension of cognitive workload and distraction was generally considered to be important by all stakeholders. The majority of luxury consumers (75%) also agreed that this dimension is important to consider. Nevertheless, the spread of the IQR for this group indicates that luxury consumers have different perspectives regarding the importance of cognitive workload and distraction. Zhang and Zhao (2019) showed that Chinese luxury consumers with different types of personal values, also value different aspects of luxury. The observed differences regarding the agreement with cognitive workload and distraction might thus be due to the different personal values of these consumers. Based on these personal values, some luxury consumers might value aspects regarding cognitive workload and distraction, whereas other consumers might put more emphasis on aspects regarding stimulation and innovation. Nevertheless, aspects regarding cognitive workload and distraction are generally agreed to be important to consider when designing infotainment systems for luxury cars.

7.1.2. Relative Importance of Dimensions

The results of the pairwise comparisons were used to derive the relative importance of the dimensions for each group of respondents. Regular consumers and designers appeared to have similar rankings regarding the importance of the dimensions. Both groups showed the highest priority values, rankings, and probabilities for perceived usability and cognitive workload and distraction, suggesting that these dimensions are the most important dimensions to consider. These findings are in line with the results of the literature review indicating that these aspects were most frequently assessed. Moreover, aspects related to perceived usability and cognitive workload and distraction are closely related to the functional value and the (perceived) safety of the system. The findings thus confirm the idea that driving safety and the functional value of the system should be established first (Şener, 2019; Song, 2020).

The priority values obtained for positive affiliation, stimulation and innovation, and overall attractiveness are lower than the values obtained for perceived usability and cognitive workload and distraction. This indicates that these three dimensions are considered less important compared to perceived usability and cognitive workload and distraction. The priority values of positive affiliation, stimulation and innovation, and overall attractiveness are quite similar and the confidence intervals are largely overlapping. Together with the close mean rankings, and the larger probabilities of a tie for these dimensions, these results suggest that these three dimensions can be considered almost equally important. These results confirm the idea that once usability and safety-related aspects have been established, more hedonic qualities should be considered to enhance the quality of the user experience resulting from infotainment systems (Hassenzahl, 2008b) and increase perceptions of luxury (Şener, 2019).

The dimension of prestige and exclusivity appears to be the least important to consider according to consumers of regular cars and designers. The priority values, rankings and probabilities obtained for this dimension were the lowest of all dimensions. According to Vigneron and Johnson (2004), aspects regarding prestige and exclusivity appear to be especially relevant in the context of luxury products. Therefore, this dimension might not be regarded least important by regular consumers. Designers also indicate this dimension to be least important when considering luxury infotainment systems, they seem to consider other dimensions of UX more important when designing infotainment systems for luxury cars.

Overall, the results indicate that consumers of regular cars and designers consider the dimensions of perceived usability and cognitive workload to be most important, followed by positive affiliation, overall attractiveness, and stimulation and innovation. Aspects regarding prestige and exclusivity are the least important to consider according to these stakeholders.

The similar rankings of the dimensions in both groups indicate that the mental models of designers appear to be aligned with those of regular consumers. This suggests that designers might use their knowledge about the needs and preferences of regular car consumers to design infotainment systems for luxury cars. This is surprising, as designers were specifically asked about the most important dimensions to consider when designing infotainment systems for luxury cars. The mental models of designers were therefore expected to be more similar to those of luxury consumers.

In contrast, the results show that the mental models of luxury consumers appear to differ from those of designers. Regarding luxury consumers, the small differences between the priority values of all dimensions, the largely overlapping credibility intervals, the inconsistent rankings, and the higher probabilities of a tie suggest that luxury consumers consider all dimensions almost equally important. These results are in line with previous literature (e.g., Şener, 2019; Vigneron & Johnson, 2004). This literature suggests that hedonic quality aspects should be valued more in the context of luxury and that expectations regarding all dimensions appear to be higher (i.e., all dimensions are more important in the context of luxury products). Luxury consumers might strive for an optimal balance between all dimensions, desiring the best possible option for each dimension. However, designers show differences regarding the relative importance of the dimensions. For example, perceived usability is considered one of the most important dimensions by designers, whereas this dimension is considered relatively less important by consumers of luxury cars.

These differences between the relative importance of the dimensions for luxury consumers and designers indicate that there is a mismatch between the mental models of these stakeholders. This mismatch suggests that designers might not have an accurate understanding of the needs and expectations of luxury consumers (Hsu et al., 2000). This is problematic, since this could result in an infotainment system that fails to meet the user's expectations, which can negatively impact the quality of UX. To prevent this, designers should get a better understanding of the mental models of luxury car consumers and align their own mental models accordingly in order to design infotainment systems that result in positive experiences (Filippi & Barattin, 2017; Hsu et al., 2000). The results of the survey can help designers understand the mental models of luxury consumers. These results indicate that luxury consumers appear to value all dimensions almost equally. This could suggest that designers should put relatively less emphasis on aspects regarding the perceived usability of the system, and focus more on hedonic quality aspects when designing infotainment systems for luxury cars.

7.2. Redesigned Framework Based on Survey

Based on the results from the online survey, the preliminary framework for assessing the UX of (luxury) infotainment systems can be refined. This framework can be used both as a tool to check design requirements as well as a tool to guide the evaluation at later stages of design. Apart from specifying what dimensions of UX are important to consider when designing IVIS, the framework also provides the relative importance of these dimensions. This will help designers to adequately prioritize the most important aspects to consider during each stage of the design process.

Based on the relative importance of the dimensions as indicated by the results of the survey, three levels of priority could be distinguished. First of all, perceived usability and cognitive workload and distraction should be established. Designers should make sure that the system is usable, and that interaction leads to minimal cognitive workload and distraction. Once this has been achieved, designers can move on to the second level of priority. This level includes the following dimensions of UX: positive affiliation, stimulation and innovation, and overall attractiveness. Here, designers should focus on more hedonic quality aspects to improve the quality of UX and enhance perceptions of luxury. Lastly, designers could focus on aspects regarding prestige and exclusivity. As this dimension is generally considered least important, it should receive the lowest priority. An overview of the redesigned framework can be found in Table 10.

Table 10

Framework for Assessing UX of Infotainment Systems including Potential Items

Priority level	Dimension	Potential items
1	Perceived usability	*The system appears to be:* • Impractical/practical • Unpredictable/predictable • Complicated/simple
	Cognitive workload and distraction	*Interacting with the system is:* • Not distracting/distracting • Undemanding/demanding • Effortless/effortful

Priority level	Dimension	Potential items
2	Positive affiliation	*Interacting with the system makes me:* • Unhappy/happy • Frustrated/pleased • Bored/excited
	Stimulation and innovation	*The system appears to be:* • Not interesting/interesting • Conservative/innovative • Unimaginative/creative
	Overall attractiveness	*The system appears to be:* • Bad/good • Unpleasant/pleasant • Ugly/attractive
3	Prestige and exclusivity	*The system appears to be:* • Tacky/stylish • Isolating/connective • Cheap/premium

It must be noted that the results of both the literature review and the survey suggest that hedonic quality aspects should be emphasized more in the context of luxury cars. This is in line with the framework proposed by Vigneron and Johnson (2004). They proposed five dimensions that distinguish luxury brands from non-luxury brands, namely: conspicuousness, uniqueness, quality, hedonism, and the extended self. Four out of five of these dimensions are related to hedonic quality aspects as represented in the second and third levels of priority. This suggests that these aspects might distinguish a luxurious infotainment system from a regular system. Specifically, three out of the five of these dimensions (i.e., conspicuousness, uniqueness, and extended self) are related to the dimension of prestige and exclusivity. This suggests that although aspects regarding this dimension are generally considered least important, these aspects might differentiate a luxury infotainment system from a regular system and could thus be especially important to consider in the context of luxury cars. In other words, establishing the quality of dimensions of UX regarding the first priority level is required, whereas aspects regarding the dimensions in levels two and three might generate added value and enhance the perceived luxuriousness of the system.

Moreover, designers should keep in mind that all dimensions are interconnected and cannot be viewed in isolation. Changes regarding one dimension are likely to yield changes in other dimensions as well. For example, making the system easier to use (i.e., enhancing perceived usability) might also result in more positive emotions (i.e., enhanced positive affiliation). In contrast, adding innovative elements (i.e., enhance stimulation and innovation) can also make the system more complex, leading to decreased usability of the system. Therefore, designers should make sure that improvements regarding one dimension will not have a negative effect on other dimensions.

Designers should also acknowledge the values of the brand. Although the usability and the safety of the system should always be established first, dimensions related to hedonic quality aspects (i.e., stimulation and innovation, positive affiliation, and overall attractiveness) appear to be equally important and can thus be emphasized in accordance with the brand values. In the study by Øvad and colleagues (2020), for example, internal discussions were held with the UX team of the brand and other stakeholders to identify the most relevant aspects regarding the company's product portfolio and brand identity. Sen and Sener (2020) even adjusted items of the AttrakDiff to better suit the brand identity and the luxury experience. Although the goal of this work is to create a universal framework for the design and evaluation of luxury infotainment systems, brands may differ in the extent to which they value certain aspects. Designers should thus use the framework as a foundation and use their knowledge about the brand values to further guide the design process and choose appropriate tools for assessment.

Apart from guiding the design process, the framework is also intended to help guide the evaluation of the quality of UX of infotainment systems at later stages of development. In this sense, the framework provides the most important dimensions to assess. As discussed in section 4.2., there are many standardized tools available to assess the identified dimensions regarding the UX of infotainment systems. However, the questionnaires we examined have different answer formats which makes it hard to aggregate and compare the data obtained from different questionnaires (Minge et al., 2016; Schrepp & Thomaschewski, 2019). In addition, filling out different types of questionnaires might be confusing for participants (Minge et al., 2016). Therefore, UX evaluation of infotainment systems would benefit from one encompassing questionnaire that contains the most important aspects to assess. Moreover, the items used in this questionnaire would provide designers with more specific indications of important aspects to consider while designing infotainment systems.

As existing standardized tools, such as the AttrakDiff and the UEQ, offer a range of items that could be used to assess the dimensions included in the framework. These questionnaires can be used to extract relevant items for the six identified dimensions regarding the UX of IVIS. Appendix C provides an overview of relevant items used in standardized tools for each dimension. Based on this overview and the underlying aspects from the literature (see Table 2), three of the most relevant items for each dimension, according to the author, are listed in Table 10. Further research should validate these (and other) items and extend the framework by creating a questionnaire that can be used to evaluate the UX of IVIS.

7.3. Limitations

It must be noted that there are limitations to this research. First of all, only two of the major digital libraries were consulted to obtain the records included in the literature review. In addition, only articles published in scientific journals were included in the review. This excludes unscientific articles written by companies or designers published on websites or blogs, which might also include relevant aspects and methods for assessing the UX of IVIS.

Another limitation of the review is that the key aspects identified are mainly based on the literature on UX for general IVIS. The small number of studies on the UX of luxury products makes it hard to draw conclusions regarding the most relevant aspects of UX to assess in the context of luxury IVIS. Moreover, participants in those studies were not always actual consumers of luxury products. Some studies asked people available on campus to participate (Morillo et al., 2019), whereas others included professionals in the field (Berger et al., 2021). The results of these studies might thus reflect an approximation of the perceptions of luxury consumers. While these results can be informative, the perceptions of luxury consumers are likely to differ from regular consumers and professionals, as reflected by the results of this study. Therefore, future studies on luxury UX could benefit from using actual luxury consumers as participants to get a better idea of the mental model of luxury consumers.

Regarding the online survey, some limitations can be observed as well. First of all, the low number of respondents in the group of luxury consumers that completed the survey resulted in questionable reliability of these results. Although the number of responses of designers was also mediocre, their results appeared to be relatively consistent as indicated by the relatively lower standard deviations. Conversely, the relatively large standard deviations for the rankings of luxury consumers indicate that there are substantial differences between luxury consumers regarding their mental models. Therefore, conclusions regarding the mental

models of luxury consumers should be taken with caution. More insights from luxury consumers are required to accurately represent their mental modes.

In addition, there appeared to be widely differing views regarding the importance of the dimension of prestige and exclusivity among both groups of consumers. Apart from personal differences within these groups, this might be due to the accuracy and interpretation of the description used in the survey. According to Hsu and colleagues (2000) the same terms can have different meanings for designers and users. The terms used to describe prestige and exclusivity might not have been clear enough for consumers, resulting in different interpretations of this dimension and thus different responses. Regarding designers, the results indicated that designers interpreted this dimension similarly, suggesting that the terms used were clear for this group of respondents.

Lastly, as with any survey or other method to obtain people's opinions in hypothetical situations, there was a risk of hypothetical bias (Penn & Hu, 2018). In other words, the dimensions that people might indicate to be most important to consider while responding to this survey might differ from the dimensions they would actually consider while buying a (luxury) product. For example, people might indicate on the survey that they consider cognitive workload and distraction to be most important, while aspects regarding stimulation and innovation of the infotainment system might predominate when actually making a purchase decision. Further research should take the effect of hypothetical bias into account and use mitigation techniques as proposed by Penn and Hu (2018).

7.4. Directions for Future Research

Altogether, the current work has laid the foundations of a framework for assessing infotainment systems. Six dimensions that are considered important contributors to the quality of UX of the system were identified and the relative importance of these dimensions has been established. Further research could extend this framework by creating a questionnaire for assessing the quality of UX of infotainment systems. The items listed in Table 10 can be used as a foundation. Once a preliminary questionnaire has been created, the psychometric properties of this questionnaire should be established by factor analysis. Further research could even create benchmarks to facilitate designers to establish the quality of UX of the infotainment system and to compare this to other systems. In order to strengthen the framework, more information about the preferences of luxury consumers regarding the UX of infotainment systems should be retrieved to get a better understanding of their mental models.

Apart from extending the framework, further research could explore the importance of the identified dimensions for passenger interaction. Since passengers need to pay little or no attention to the driving task, aspects regarding cognitive workload and distraction might not be as important to consider (Sen & Sener, 2020), and other aspects (e.g., aspects regarding stimulation and innovation) might receive higher priority. In addition, the currently occurring shift towards more autonomous driving experiences might even cause drivers to be passengers for most of the time (Kun et al., 2016). Although full autonomous driving remains something for the future, relevant dimensions regarding the UX of infotainment systems for passengers and 'drivers' of autonomous cars might already be explored.

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APPENDIX A

Overview of dimensions assessed by each study included in literature review

Articles	***Dimension 1*** **Perceived usability**	***Dimension 2*** **Prestige and exclusivity**	***Dimension 3*** **Stimulation and innovation**	***Dimension 4*** **Overall attractiveness**	***Dimension 5*** **Cognitive workload and distraction**	***Dimension 6*** **Positive affiliation**
Articles on infotainment systems						
1. Jung et al. (2021)	X				X	
2. Čegovnik et al. (2020)	X	X	X	X	X	
3. Young et al. (2020)	X					
4. Khan et al (2020)	X		X		X	
5. Berger et al (2019)	X	X	X	X		
6. Frison et al. (2019)	X	X	X	X		X
7. Galarza & Paradells (2019)				X		
8. Biondi et al. (2019)	X				X	X
9. Kula et al. (2017)			X		X	X
10. Lux et al. (2018)	X	X	X	X	X	
11. Ingi Árnason et al (2014)	X			X	X	
12. Farooq et al. (2014)				X		X
13. Broy et al. (2012)	X	X	X	X	X	
14. Charissis et al. (2021)	X					
15. Kim and Yoo (2021)	X	X	X	X		
16. Park & Im (2020)					X	
17. Prabhakar et al. (2020)	X				X	
18. Kim et al. (2020)	X				X	
19. Caon et al. (2020)	X					
20. Wang et al. (2019)			X	X	X	
21. Jung et al. (2019)	X			X		X

Articles	***Dimension 1*** **Perceived usability**	***Dimension 2*** **Prestige and exclusivity**	***Dimension 3*** **Stimulation and innovation**	***Dimension 4*** **Overall attractiveness**	***Dimension 5*** **Cognitive workload and distraction**	***Dimension 6*** **Positive affiliation**
22. Grogna et al. (2018)					X	
23. Jang et al. (2017)	X					
24. Sterkenburg et al. (2017)					X	
25. Buchhop et al. (2017)					X	
26. Shakeri et al. (2017)					X	
27. Feng et al. (2017)					X	
28. Wang et al. (2017)			X		X	
29. Angelini et al. (2016)	X				X	X
30. May et al. (2016)					X	
31. Winkler et al. (2016)	X		X		X	
32. Reichel et al. (2015)	X			X		X
33. Chen et al. (2015)	X					X
34. May et al. (2014)					X	
35. Lauber et al. (2014)	X				X	
36. Parada-Loira et al. (2014)				X	X	
37. Macek et al. (2013)	X			X	X	X
38. Pfleging et al. (2012)	X				X	
39. Pakkanen et al. (2012)				X	X	
40. Garzon (2012)	X	X	X	X	X	
41. Pitts et al. (2012)		X	X	X	X	
42. Döring et al. (2011)	X			X	X	
Articles on luxury products						
43. Berger et al. (2021)	X	X	X	X		
44. Sen & Sener (2020)	X	X	X			
45. Coudounaris (2018)		X	X	X		
46. Qi & Jang (2021)	X					

Articles	***Dimension 1*** **Perceived usability**	***Dimension 2*** **Prestige and exclusivity**	***Dimension 3*** **Stimulation and innovation**	***Dimension 4*** **Overall attractiveness**	***Dimension 5*** **Cognitive workload and distraction**	***Dimension 6*** **Positive affiliation**
47. Øvad et al. (2020)	X	X	X			
48. Ramadan (2019)	X	X				
49. Altarteer et al. (2017)	X	X	X			
50. Morillo et al. (2019)	X			X		
Luxury products (n = 8*)*	88% (*n* = 7)	75% (*n* = 6)	62% (*n* = 5)	38% (*n* = 3)		
Infotainment systems (n = 42)	61% (*n* = 26)	19% (*n* = 8)	30% (*n* =13)	43% (*n* = 18)	71% (*n* = 30)	21% (*n* = 9)
Total (N = 50)	66% (*n* = 33)	28% (*n* =14)	36% (*n* =18)	42% (*n* = 21)	60% (*n* = 30)	18% (*n* = 9)

APPENDIX B

Survey on Agreement and Importance of Potential Dimensions of UX for IVS

Introduction to survey

Dear respondent,

You are being invited to participate in a research study conducted by Sanne van Eck under the supervision of Dr. Simone Borsci from the Faculty of Behavioural, Management and Social Sciences at the University of Twente in collaboration with a design company.

The research explores the quality of infotainment systems for cars. These infotainment systems are the multifunctional interfaces in the dashboard of cars that can provide information about the functioning of the car (such as speed, gas level, climate control etc.), as well as other functionalities such as navigation, communication, digital radio, and other multimedia and entertainment functions.

GOAL

This research aims to investigate the key aspects people are looking at when assessing the quality of infotainment systems.

WHAT WE ARE ASKING YOU TO DO

Please answer the questions in this survey on the basis of your previous experience with cars and your knowledge and beliefs. There are no right or wrong answers, we are only interested in your opinion.

HOW MUCH TIME IT WILL TAKE YOU TO ANSWER

The survey will take approximately 15 minutes to complete.

USAGE OF THE COLLECTED DATA

- Your participation in this study is entirely voluntary and you can withdraw at any time.
- There are no risks associated with this research study; however, as with any online related activity, the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential.
- We will minimize any risks by having the data anonymized and stored at the University of Twente.
- The data will not be connected to any personal information other than gender, age, and nationality and will be treated anonymously.
- For more information, questions, or comments, please contact the researcher (Sanne van Eck) via s.vaneck@student.utwente.nl.

CONSENT

By clicking on the 'Agree' button I indicate that:

- I read the information above
- I am 18 years of age or older
- I voluntarily agree to participate

- o Agree
- o Disagree

Demographic questions:

Sex (as assigned at birth)

- o Male
- o Female

What is your current gender identity? (check all that apply)

- o Man
- o Woman
- o Female-to-Male (FTM)/Transgender Male/Trans Man
- o Male-to-Female (MTF)/Transgender Female/Trans Woman
- o Genderqueer, neither exclusively male or female
- o Additional Gender Category/(or Other), please specify
  _____
- o Decline to answer

Please confirm you're not a robot

Please indicate your age

Please indicate your nationality

- Dutch
- Italian
- German
- Belgian
- French
- Spanish
- British
- Swiss
- American
- Other, please specify _____

I perform this survey from the perspective of a:

- Designer of infotainment systems
- Car owner

Part 1 for designers

When designing the infotainment system for a **luxury** car, it is important to evaluate the quality of the system. Previous research suggests that six aspects seem to be important to consider when evaluating the quality of **luxury** infotainment systems.

In the first part of this survey, each aspect that appears important for the evaluation of **luxury** infotainment systems will be introduced. Consequently you will be asked to what extent you agree that these aspects are important to consider when designing an infotainment system for **luxury** cars.

Low distraction and low demand on attention: ‘An infotainment system should not distract a driver and should not be demanding in terms of cognitive workload and attention’.

To what extent do you agree that *low distraction and low demand on attention* are important to consider when you are designing an infotainment system for a luxury car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Easiness of use: 'An infotainment system should be easy to comprehend, navigate and use to execute the desired tasks.'

To what extent do you agree that the *easiness of use* is important to consider when you are designing an infotainment system for a luxury car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Overall appeal: 'An infotainment system should overall appear to be good, likeable, and attractive.'

To what extent do you agree that the *overall appeal* is important to consider when you are designing an infotainment system for a luxury car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

***Innovativeness**:* 'An infotainment system should be interesting and innovative, stimulating curiosity.'
To what extent do you agree that *innovativeness* is important to consider when you are designing an infotainment system for a luxury car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Prestigiousness: 'An infotainment system should seem prestigious and exclusive, conveying social status.'
To what extent do you agree that *prestigiousness* is important to consider when you are designing an infotainment system for a luxury car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Positive feelings: 'An infotainment system should stimulate positive emotions and attitudes towards the system, interacting with the system should make the user happy.'
To what extent do you agree that the stimulation of *positive feelings* is important to consider when you are designing an infotainment system for a luxury car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Part 2 for designers

In the second part of this survey the aspects that you rated before will be presented to you in pairs. For every pair, you are asked to indicate which aspect you consider to be more important to assess the quality of infotainment systems for **luxury** cars.

Aspects & Descriptions

Low distraction and low demand on attention	An infotainment system should not distract a driver and should not be demanding in terms of cognitive workload and attention
Easiness of use	An infotainment system should be easy to comprehend, navigate and use to execute the desired tasks
Overall appeal	An infotainment system should overall appear to be good, likeable, and attractive.
Innovativeness	An infotainment system should be interesting and innovative, stimulating curiosity
Prestigiousness	An infotainment system should seem prestigious and exclusive, conveying social status
Positive feelings	An infotainment system should stimulate positive emotions and attitudes towards the system, interacting with the system should make the user happy

---

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?
Low distraction and low demand on attention *or* ***Easiness of use***

- o Low distraction and low demand on attention is more important
- o Low distraction and low demand on attention is slightly more important
- o Both aspects are equally important
- o Easiness of use is slightly more important
- o Easiness of use is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Low distraction and low demand on attention *or* ***Overall appeal***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Overall appeal is slightly more important
- Overall appeal is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Low distraction and low demand on attention or ***Innovativeness***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Innovativeness is slightly more important
- Innovativeness is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Low distraction and low demand on attention or ***Prestigiousness***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Low distraction and low demand on attention *or* ***Positive feelings***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Easiness of use or ***Overall appeal***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Overall appeal is slightly more important
- Overall appeal is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Easiness of use or ***Innovativeness***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Innovativeness is slightly more important
- Innovativeness is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Easiness of use or ***Prestigiousness***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Easiness of use or ***Positive feelings***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Overall appeal or ***Innovativeness***

- Overall appeal is more important
- Overall appeal is slightly more important
- Both aspects are equally important
- Innovativeness is slightly more important
- Innovativeness is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Overall appeal *or* ***Prestigiousness***

- Overall appeal is more important
- Overall appeal is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Overall appeal *or* ***Positive feelings***

- Overall appeal is more important
- Overall appeal is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Innovativeness *or* ***Prestigiousness***

- Innovativeness is more important
- Innovativeness is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Innovativeness *or* ***Positive feelings***

- Innovativeness is more important
- Innovativeness is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important

Positive feelings is more important

Which aspect do you consider more important for the quality of infotainment systems for luxury cars?

Prestigiousness or ***Positive feelings***

- Prestigiousness is more important
- Prestigiousness is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Concluding part

Please add any aspects you would consider important for the assessment of luxury infotainment systems that we missed to propose.

Please write down below:

This is the end of the survey. Thank you very much for your response!
Based on the responses we hope to derive what aspects are most important to consider when designing infotainment systems for luxury cars.
Are you willing to help us with further steps? Then please leave your e-mail and we might be in touch.

Any further questions or comments? Please let me know! You can send an e-mail to: s.vaneck@student.utwente.nl

Further introductory questions for consumers of cars

My car is considered a:

- Luxury Car
- Regular Car

Please report the brand and the model of your car

First part for consumers of luxury cars

When considering to buy a **luxury** car, it is important to evaluate the quality of the infotainment system. Previous research suggests that six aspects seem important when considering the quality of infotainment systems for **luxury** cars.

In the first part of this survey, each aspect that appears important for the evaluation of **luxury** infotainment systems will be introduced. Consequently, you will be asked to what extent you agree that these aspects are important to consider when assessing the quality of an infotainment system of a **luxury** car you would like to buy.

Low distraction and low demand on attention: ‘The infotainment system seems designed so that it will not distract me while I am driving and it seems not demanding in terms attention’.
To what extent do you agree that *low distraction and low demand on attention* by the infotainment system is important to consider when you are deciding to buy a luxury car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Easiness of use: 'The infotainment system seems easy to comprehend, navigate and use to execute the necessary tasks.'
To what extent do you agree that the *easiness of use* of the infotainment system is important to consider when you are deciding to buy a luxury car?
Strongly disagree

- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Overall appeal: 'The infotainment system overall seems to be good, likeable, and attractive.'
To what extent do you agree that the *overall appeal* of the infotainment system is important to consider when you are deciding to buy a luxury car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Innovativeness: 'The infotainment system seems interesting and innovative and it stimulates my curiosity.'

To what extent do you agree that the *innovativeness* of the infotainment system is important to consider when you are deciding to buy a luxury car?

Strongly disagree

- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Prestigiousness: 'The infotainment system seems prestigious and exclusive.'

To what extent do you agree that the *prestigiousness* of the infotainment system is important to consider when you are deciding to buy a luxury car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Positive feelings: 'The infotainment system stimulates immediate positive emotions, interacting with the system makes me happy.'

To what extent do you agree that the *positive feelings* resulting from interaction with the infotainment system are important to consider when you are deciding to buy a luxury car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Part 2 for consumers of luxury cars

In the last part of this survey the aspects that you rated before will be presented to you in pairs. For every pair, you are asked to indicate which aspect of the infotainment system you consider more important when buying a car.

Aspects & Descriptions

Low distraction and low demand on attention	The infotainment system seems designed so that it will not distract me while I am driving and it seems not demanding in terms attention
Easiness of use	The infotainment system seems easy to comprehend, navigate and use to execute the necessary tasks
Overall appeal	The infotainment system overall seems to be good, likeable, and attractive
Innovativeness	The infotainment system seems interesting and innovative and it stimulates my curiosity
Prestigiousness	The infotainment system seems prestigious and exclusive
Positive feelings	The infotainment system stimulates immediate positive emotions, interacting with the system makes me happy

---

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Low distraction and low demand on attention or ***Easiness of use***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Easiness of use is slightly more important
- Easiness of use is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Low distraction and low demand on attention or ***Overall appeal***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Overall appeal is slightly more important
- Overall appeal is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Low distraction and low demand on attention or ***Innovativeness***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Innovativeness is slightly more important
- Innovativeness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Low distraction and low demand on attention or ***Prestigiousness***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Low distraction and low demand on attention *or* ***Positive feelings***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Easiness of use or ***Overall appeal***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Overall appeal is slightly more important
- Overall pleasure is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Easiness of use or ***Innovativeness***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Innovativeness is slightly more important
- Innovativeness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Easiness of use or ***Prestigiousness***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Easiness of use or ***Positive feelings***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Overall appeal *or* ***Innovativeness***

- Overall appeal is more important
- Overall appeal is slightly more important
- Both aspects are equally important
- Innovativeness is slightly more important
- Innovativeness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Overall appeal or ***Prestigiousness***

- Overall appeal is more important
- Overall appeal is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Overall appeal *or* ***Positive feelings***

- Overall appeal is more important
- Overall appeal is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Innovativeness *or* ***Prestigiousness***

- Innovativeness is more important
- Innovativeness is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Innovativeness *or* ***Positive feelings***

- Innovativeness is more important
- Innovativeness is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for luxury cars?

Prestigiousness or ***Positive feelings***

- Prestigiousness is more important
- Prestigiousness is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Part 1 for regular consumers

When considering to buy a car, it is important to evaluate the quality of the infotainment system. Previous research suggests that six aspects seem important when considering the quality of infotainment systems for cars.

In the first part of this survey, each aspect that appears important for the evaluation of infotainment systems will be introduced. Consequently, you will be asked to what extent you agree that these aspects are important to consider when assessing the quality of an infotainment system of a car you would like to buy.

Low distraction and low demand on attention: ‘The infotainment system seems designed so that it will not distract me while I am driving and it seems not demanding in terms attention’.
To what extent do you agree that *low distraction and low demand on attention* by the infotainment system is important to consider when you are deciding to buy a car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Easiness of use: 'The infotainment system seems easy to comprehend, navigate and use to execute the necessary tasks.'
To what extent do you agree that the *easiness of use* of the infotainment system is important to consider when you are deciding to buy a car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Overall appeal: 'The infotainment system overall seems to be good, likeable, and attractive.'
To what extent do you agree that the *overall appeal* of the infotainment system is important to consider when you are deciding to buy a car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Innovativeness: 'The infotainment system seems interesting and innovative and it stimulates my curiosity.'

To what extent do you agree that the *innovativeness* of the infotainment system is important to consider when you are deciding to buy a car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Prestigiousness: 'The infotainment system seems prestigious and exclusive.'

To what extent do you agree that the *prestigiousness* of the infotainment system is important to consider when you are deciding to buy a car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Positive feelings: 'The infotainment system stimulates immediate positive emotions, interacting with the system makes me happy.'

To what extent do you agree that the positive feelings resulting from interaction with the infotainment system are important to consider when you are deciding to buy a car?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

Part 2 for regular consumers

Aspects & Descriptions

Low distraction and low demand on attention	The infotainment system seems designed so that it will not distract me while I am driving and it seems not demanding in terms attention
Easiness of use	The infotainment system seems easy to comprehend, navigate and use to execute the necessary tasks
Overall appeal	The infotainment system overall seems to be good, likeable, and attractive
Innovativeness	The infotainment system seems interesting and innovative and it stimulates my curiosity
Prestigiousness	The infotainment system seems prestigious and exclusive
Positive feelings	The infotainment system stimulates immediate positive emotions, interacting with the system makes me happy

---

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Low distraction and low demand on attention or ***Easiness of use***

- o Low distraction and low demand on attention is more important
- o Low distraction and low demand on attention is slightly more important
- o Both aspects are equally important
- o Easiness of use is slightly more important
- o Easiness of use is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Low distraction and low demand on attention or ***Overall appeal***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Overall appeal is slightly more important
- Overall appeal is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Low distraction and low demand on attention or ***Innovativeness***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Innovativeness is slightly more important
- Innovativeness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Low distraction and low demand on attention or ***Prestigiousness***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Low distraction and low demand on attention or ***Positive feelings***

- Low distraction and low demand on attention is more important
- Low distraction and low demand on attention is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Easiness of use or ***Overall appeal***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Overall appeal is slightly more important
- Overall pleasure is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Easiness of use or ***Innovativeness***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Innovativeness is slightly more important
- Innovativeness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Easiness of use or ***Prestigiousness***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Easiness of use or ***Positive feelings***

- Easiness of use is more important
- Easiness of use is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Overall appeal *or* ***Innovativeness***

- Overall appeal is more important
- Overall appeal is slightly more important
- Both aspects are equally important
- Innovativeness is slightly more important
- Innovativeness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Overall appeal or ***Prestigiousness***

- Overall appeal is more important
- Overall appeal is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Overall appeal *or* ***Positive feelings***

- Overall appeal is more important
- Overall appeal is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Innovativeness *or* ***Prestigiousness***

- Innovativeness is more important
- Innovativeness is slightly more important
- Both aspects are equally important
- Prestigiousness is slightly more important
- Prestigiousness is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Innovativeness *or* ***Positive feelings***

- Innovativeness is more important
- Innovativeness is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Which aspect do you consider more important for you to establish the quality of infotainment systems for cars?

Prestigiousness or ***Positive feelings***

- Prestigiousness is more important
- Prestigiousness is slightly more important
- Both aspects are equally important
- Positive feelings is slightly more important
- Positive feelings is more important

Concluding question for regular consumers

Please add any aspects you would consider important for the assessment of infotainment systems that we missed to propose.

Please write down below:

This is the end of the survey. Thank you very much for your response!
Based on the responses we hope to derive what aspects are most important to consider when designing infotainment systems for cars.
Are you willing to help us with further steps? Then please leave your e-mail and we might be in touch.

Any further questions or comments? Please let me know! You can send an e-mail to:
s.vaneck@student.utwente.nl

APPENDIX C

List of items used in UEQ+ and AttrakDiff complemented with items based on other questionnaires found in literature

Perceived usability:

To achieve goals, I consider the product

- Slow/fast
- Inefficient/efficient
- Impractical/practical
- Organized/cluttered

Handling and using the product is:

- Not understandable/understandable
- Difficult to learn/easy to learn
- Complicated/easy
- Clear/confusing

The reactions of the product to input and command are:

- Unpredictable/predictable
- Obstructive/supportive
- Not secure/secure
- Does not meet expectations/meets expectations

- Technical/human
- Complicated/simple
- Cumbersome/straightforward
- Confusing/clearly structured

Cognitive workload and distraction

Interaction with the system is:

- Not distracting/distracting
- Undemanding/demanding
- Stressful/relaxing
- Interfering with driving/not interfering
- effortless/effortful

- Not requiring concentration/requiring concentration

Overall attractiveness

The system is generally:

- Annoying/enjoyable
- Bad/good
- Unpleasant/pleasant
- Unfriendly/friendly
- ugly/attractive
- disagreeable/likeable
- rejecting/inviting
- repelling/appealing
- discouraging/motivating

Stimulation and innovation

Handling and working with the product is:

- Inferior/valuable
- Boring/exciting
- Not interesting/interesting
- Demotivating/motivating

The idea behind the product and its design are:

- Unimaginative/creative
- Conventional/inventive
- Common/cutting edge
- Conservative/innovative
- Cautious/bold
- Ordinary/novel
- Dull/captivating
- Undemanding/challenging

Prestige and exclusivity

The visual design of the system is:

- Ugly/beautiful
- tacky/stylish
- Unappealing/appealing

- Unpleasant/pleasant
- Isolating/connective
- Unprofessional/professional
- Cheap/premium
- Alienating/integrating
- Separates me/brings me closer
- Unpresentable/presentable
- Unexclusive/exclusive (luxury related)

Positive affiliation

Interacting with the systems makes me:

- Unhappy/happy
- frustrated/pleased
- sad/happy
- Bored/excited
- Exhausted/euphoric
- Tired/calm
- Passive/active