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The connection between impressions, user experience and design specifications in technology-driven products

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Abstract

In this study, the relationship between user experience, product appearance and emotional impressions generated by the user are examined through electric concept cars introduced by automotive companies in motor shows. The focus of the research is on the measurement of the emotional experiences that the interior design of the electric concept cars awakens in the user. The main purpose of the study is to open a discussion on the relation between the emotional impressions and product appearance.

Keywords: industrial design, user experience, design evaluation

1. Introduction

Experience is very broad term that is widely used in the literature in various contexts. Although the term tries to understand and explore users' relations with products or systems, the product can be a tangible product such as an electric bicycle, refrigerator etc., a digital product such as e-commerce web-site, a mobile application or a product-service system such as a e-scooter sharing system or a food ordering service. Different models have been discussed in the literature in order to explore this concept from different point of views. Desmet and Hekkert's (2007) model is more focused to tangible products and has point of view from product qualities. Forlizzi and Battarbee's (2004) model and McCarthy and Wright's (2004) model are more focuses on the interaction resulting from the usage of the product by users and its more often applied on interactive systems. And lastly, Hassenzahl (2003) and Mahlke (2007) have proposed models from that place the user in the centre of their models. However high-technology tangible products that are also called technology-driven products in the following paragraph can be considered as a new product typology and the hedonic part of the experience with them is still is an important subject.

Electrical automobiles, due to rising environmental concerns, gas shortages, significant advancements in battery technologies as well as national and legal regulations such as the 1990 California Clean Air Act Amendment and the 1992 Energy Policy Act are gaining popularity in the global automobile markets. By year 2030 the global electric vehicle market is expected to reach 951.9 Billon USD size (Electric Vehicle Market Size, Share, Forecast, Report, 2023-2030, n.d.). As a new emerging technology, the electric powertrain has resulted with the transformation of the automobile to a "computer on wheels" and in relation with these transformations the design specifications are also changing along with the users' experiences with these automobiles. Today, nearly every global auto maker has various number of electrical models in their product portfolio. Therefore, electric automobiles can be considered as products that are based on new and/or emerging technologies. These type of products are also described as technology driven products (Ulrich et al., 2020).

Based on the facts stated above, this study aims to explore the relationship between anticipated experiences of users and design specifications in technology-driven products in the case of electric automobiles. The relation between expected user experience and design specifications represents a topic with significant research potential. Based on this purpose, this study aims to find answers to the following research question:

- *What is the relationship between user experience and design specifications in technology-driven products?*
- *Which interior components do users think is relevant to the user experience in electric cars?*
- *Can a hierarchical order be made among these interior components?*

2. Anticipated user experience

For nearly 20 years the field of User-Experience gained significant importance especially in the field of Human-Computer Interaction (HCI). Beginning from the early 1980's the main focus of HCI was about usability of personal computers and other computerized systems and consumer products aiming to make computer user-interfaces more effective, efficient and satisfactory for their users. However, this approach began to fall short to fully understand the interaction among users and computer user-interfaces. Around year 2000, this fact resulted with emergence of a new field called user-experience which tries to understand explore the relationship among users and computers and other product from a broader perspective. Today there are a number of user-experience models that try to understand and explore the experience that emergence as a result of the use of a product; here the product can be understood broad term bot for digital user-interface as well as tangible physical products. On the other hand, user-experience field tries to understand the experience of user based on various time periods such as, anticipated, momentary, episodic and cumulative user-experience (Roto et al., 2011).

As most of the research in the user-experience field is based on computer user-interfaces, consumer products that are becoming physical-function-oriented computers also require a special research focus and effort from the UX point of view.

In their daily lives people can have anticipations on different occasions and purposes. These anticipations are often accompanied by various emotions. People can have anticipation about a certain activity, a certain job application and its consequences and the usage and the ownership of a certain product. On the other hand, anticipation is considered to be important parameter in the user-experience field. Users' past experiences and other stimuli from different sources have an important part on their current experience on their current experiences with products. This fact also has a similar function for the future experiences in the proposed usage of future products (Arhippainen & Tähti, 2003), (Mäkelä & Suri, 2001), (Roto, 2007). McCarthy & Wright (2004) consider anticipation as one of the six sense-making processes in user-experience model. According to McCarthy & Wright (2004) anticipation refers to the possibilities, expectations, and ways of making sense that are related to users' relevant past experiences.

Desmet & Hekkert (2007) also refer to the concept of anticipation as an important part of the experience process. They assert that human-product interaction includes not only instrumental and non-instrumental interactions, but also non-physical interaction that refers to recalling, anticipating, or dreaming about a future product usage. Sward & Macarthur, (2007) considers the concept of anticipation in the context of anticipated interaction while Roto, (2007) considers as expected experience and anticipated experience (Roto et al., 2011), (Yogasara & Popovic, 2011), (Yogasara et al., 2012). On the other hand, anticipated user-experience can play important role such as design facilitator tool in the initial phases of the design process (Law, et al., 2009; Yogasara, et al., 2011, 2012).

However, despite the literature emphasis on the importance of anticipation and/or expectation on the experience for future product usage, there are a limited number of research focusing on how to explore anticipated user-experience. The study of Heikkinen et al., (2009) on expected experiences of mobile devices and the study of Olsson et al., (2012) on mobile mixed-reality services are a very few examples. The scope of these studies are very limited to the determination of users' needs for the initial phases instead of trying to explore the characteristics of the expected experiences. Tanuar et al., (2018) used prototypes to explore the anticipated user-experience of e-commerce websites. Marti & Iacono, (2016)

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used Ad Hoc questionnaires to evaluate the AUX of a fitness application that runs on a smart phone. Stylidis et al. (2023) conducted a research to explore the perceived comfort by using visual materials of car seats.

In the current literature and practice five different methods are used in the evaluation of the anticipated/expected user-experience. Generally speaking, three of these methods are based on semantic differential, one on checklist and one on heuristics. The methods are: Property Checklists, Product Semantic Analysis, Repertory Grid Technique, Multiple Sorting Technique and Playability Heuristics.

3. Methodology

Basically, this study aimed to determine the key impressions that are related with the anticipated user-experience of fully-electric vehicle show cars, in other words concept designs, as technology-driven products. To achieve this basic aim this study is structured on two phases: firstly, a card-sorting study was conducted with automobile industry experts to determine the interior parts that can be thought to be directly related with the vehicle-experience and secondly, a repertory grid analysis to explore the elements of users hedonic values towards the vehicles utilized during the experiment.

In the initial phase, to determine the primary key interior pats of a fully-electric vehicle, a card sorting study was conducted based on an electric Sport-Utility Vehicle (SUV). The card sorting technique is a methodology that is widely used in the usability field as well as in the user-experience field to determine user needs and preferences and also to establish hierarchies among various components of a system (Albert et al., 2008). The electric automobile selected for this study was a Jaguar I-Pace fully electric SUV. The reasons for the selection of this vehicle were as follows: firstly, it is a fully electric vehicle, secondly it is designed as a fully electric vehicle; not an electric version of an internal-combustion engine powered vehicle model, thirdly it was available and reachable in the Turkish market where the study was conducted. 10 participants, who were test drivers of 3 different electric automobile importers were invited to contribute the card sorting study. After conducting a test drive in an area that was closed to traffic, participants were asked to determine and group the interior elements that can be related with the user-experience and then asked to establish a hierarchy among these elements. The participants at this part of the study are coded as E1, E2 …En (E standing for Expert). The card sorting layout of each participant was analysed based on how many times each element was placed in the same group.

Figure 1. (from left to right) Nissan IMs Concept, GAC Entranze EV and Infiniti QX Inspiration

Figure 2. (from left to right) Audi Q4 E-tron Concept, Skoda Vision IV, Alfa Romeo Tonale

In the second phase of the study, a repertory grid analysis study was conducted with 50 participants (35 male and 15 female aged between 18-65 years; mean value=41,54) to explore the key impressions that are related with the anticipated user-experience based on visual interaction of the concept vehicle

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interiors. All the participants were active EV users and were informed that they were evaluating EV interiors.
The repertory grid technique (RGT) was initially developed by George Kelly in the clinical psychology field to assess people's views on other people a s well as on objects. The RGT is widely used in user-experience research to understand users' views and opinions on various aspects of products (Fallman & Waterworth, 2010). 6 concept designs of fully electric vehicles were selected as the stimulus of the RGT study. 3 of these vehicle have been on display in 2019 North American International Auto Show, Detroit, MI (Figure 1): Nissan IMs Concept, GAC Entranze EV and Infiniti QX Inspiration Concept while, 3 other vehicles have been on display in 2019 Geneva Motor Show, Geneva, Switzerland (Figure 2): Audi Q4 E-tron Concept, Skoda Vision IV, Alfa Romeo Tonale.

4. Findings

4.1. Findings of the card sorting study

At this part of the study experts who contributed to the study made a test of the stimulus vehicle, the Jaguar I-Pace, and then performed a card sorting study. Users were asked which parts of the interior (Figure 3) can be considered to be relevant to the user experience when they opened the door of the vehicle, looked at it and then sat in the driver's seat. The results of the card sorting study can be seen in Table 1.

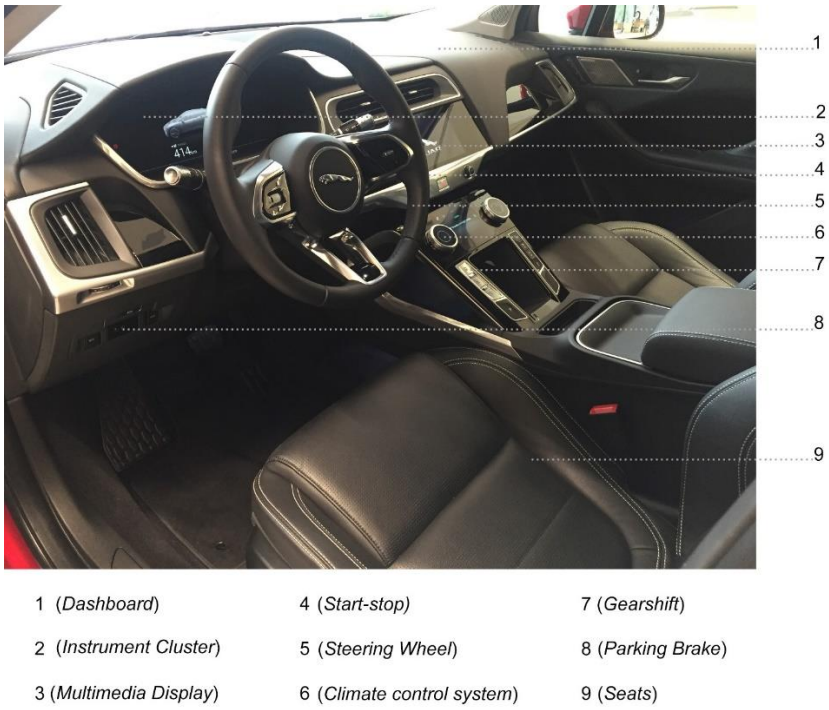

Figure 3. Interior parts that were evaluated during the card sorting study

Table 1, shows the hierarchy among interior elements have been established by the researchers, the first one being the most important: dashboard, steering wheels, multimedia system, instrument cluster and seats. Based on these findings, the authors decided to limit the focus of the RGT study with the following interior components: dashboard, steering wheels, multimedia system, instrument cluster. The participants were informed that the focus of the RGT study was consisting of the elements defined above. The reason for excluding seats was the type of interaction of the seats with the user in comparison with the other 4 elements determined above.
Each row presents a participant's selection of components that is thought to be relevant with anticipated user-experience of the cars. Some participants such as E1 and E9 identified only 3 interior components while some participants E2, E4 identified 6 components that is thought to be relevant with anticipated user-experience of the cars.

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Table 1. Results of the card sorting study conducted with industry experts

	Interior Components Related with User Experience					
Participant	1	2	3	4	5	6
E1	Dashboard	Instrument Panel	Steering Wheel	-	-	-
E2	Multimedia screen	Instrument Panel	Steering Wheel	Sunroof	Shift lever	Seats
E3	Dashboard	Sunroof	Steering Wheel	Seats	-	-
E4	Multimedia screen	Hand brake	Steering Wheel	Instrument Panel	Sunroof	Seats
E5	Dashboard	Hand brake	Multimedia screen	Instrument Panel	-	-
E6	Dashboard	Instrument Panel	Steering Wheel	Multimedia screen	Sunroof	-
E7	Multimedia screen	Seats	Instrument Panel	Sunroof	-	-
E8	Dashboard	Multimedia screen	Seats	Shift lever	-	-
E9	Seats	Instrument Panel	Multimedia screen	-	-	-
E10	Steering Wheel	Multimedia screen	Instrument Panel	Seats	Shift lever	-

4.2. Findings of the repertory grid study

Basically, the RGT analysis consists of three fundamental components: elements, constructs and opposites. In this study the elements were the 6 concept cars that were selected for the study. Combination consisting of pictures of 3 different vehicles were presented to each of 50 participants who contributed to this phase of the research and have been requested to select 2 vehicles that are thought to be similar in terms of key impressions. The automobile is a product that is strongly related with the brands identity. Therefore, in order to prevent participants from the positive and negative biases based on automobile brand identities, all logos and other items in photographs that can be related with any automobile brands were covered by the researchers.

This technique is also called the method of triads. As the result of this part of RGT analysis a total number of 84 individual key impressions (Figure 2) out of 474 items were collected from the participants. Among these 74 key impressions 12 items were selected as constructs, based on these constructs 12 opposites were generated by the researchers, to be used in the RGT analysis. These constructs and opposites were transformed into evaluation scale extremes (Table 3)

These key impressions that are resulted from the RGT study was classified by the authors into themes based-on similarities of the impressions. All the themes were classified under 8 themes as follows: appearance (22 item), emotions (19 items), usage (15 item), meaning (12 item), innovation (6 item) context of use (3 items), performance (3 item) and branding (1 item).

The grouping of the key impressions under themes shows that the majority of participants' impressions are related with the appearance of the car, followed by the emotions of the participants and followed by the key impressions related with the usage of the car. On the hand, impressions related with innovation, context of use, performance and lastly branding can be considered are other themes. However, the degree of importance and the commonality among users of these key impressions have been the focus of this study.

The ratings given by the participants to all the elements for all the constructs/opposites have been analysed by using Principal Components Analysis in Idiogrid software. This analysis resulted in locating each element in relation to each construct, in other words, key impressions related with the anticipated user-experience (Figure 4). A quick visual analysis of these graphics has shown that vehicles 2 and 3 were closely located in relation to the constructs compared to vehicles 1, 4, 5 and 6. Therefore these two clusters were separately re-analysed in order to find out the constructs- key impressions the vehicles

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have a proximity in location. It can be said that vehicles 1, 4, 5 and 6 are closely related with the following impressions related with hedonic values and meanings respectively: futuristic, suitability for today, clutteredness, attractiveness and sporty (Figure 5).

Table 2. Key impressions collected from all participants

Theme	Key impressions
Appearance	Realist, futurist, weird, old, fantastic, elegant, playful, aggressive, ugly, nostalgic, modern, classic & standard, colourful, gloomy, mad, attractive, savage, posh, arty, energetic, full of adrenalin, dangerous
Emotions	Pleasant, warm, lovely, sparkling, free, bohemian, beautiful, sexy, deep, exciting, calming, flamboyant, young, curious, serious, scary, emotional, depressing, repulsive
Usage	Unsafe, distracting, coherent, confusing, cluttered, uncomfortable, apprehensive, useful, ergonomic, spacious&bright, not ergonomic, comfortable, safe, useless, easy to use
Meaning	Luxury / expensive, powerful, feminine, noble, mix of classical and modern, iconic, cheap, economical, high quality, mysterious, uncommon
Innovation	Innovative, original, simple, modular, complicated, technologic,
Context of use	Outdoor, special purpose, sportive
Performance	Slow, silent, fast, sturdy
Branding	Belongs to a brand,

Table 3. Constructs and opposites

	Constructs	1	2	3	4	5	6	7	Opposites
1	I find the vehicle futuristic.								I find the vehicle more suitable for today.
2	I find the vehicle luxurious and/or expensive.								I find the vehicle cheap (not luxurious).
3	The vehicle creates a feeling of spaciousness.								The vehicle feels overwhelming.
4	I find the vehicle simplistic								I don't find the tool simplistic
5	I find the vehicle comfortable.								I find the vehicle uncomfortable.
6	I find the vehicle quiet and peaceful.								I do not find the vehicle quiet and peaceful.
7	I find the vehicle classical / standard.								I find the tool unusual.
8	The vehicle feels me safe.								The vehicle feels unsafe.
9	The vehicle creates a feeling of unity.								The vehicle creates the impression of cluttered
10	The vehicle feels nostalgic.								The vehicle feels modern.
11	I find the vehicle attractive.								I find the vehicle repulsive.
12	The vehicle creates the impressions of is sporty, high performance and fast.								The vehicle creates the impression of a slow vehicle.

On the other on the basis of Figure 6, it can be said that vehicle 5 and 6 are related with all the 12 hedonic impressions. These analyses we observed that the following relations between vehicles and hedonic impressions are the most powerful ones:

- Vehicle 1 has a strong relation with “futuristic” and “luxurious and/or expensiveness” impressions,
- Vehicle 2 has a strong relation with “spaciousness” impression,
- Vehicle 3 has a strong relation with “comfortableness” impression,

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- Vehicle 4 has a strong relation with ”classical/standard”, “safe” and “simplistic” impressions,
- Vehicle 5 has a strong relation with” clutteredness” impression,
- Vehicle 6 has a strong relation with “sporty, high performance and fast” and “attractiveness” impressions.

Since it is a study about trying to determine the impressions of the participants through the visuals of the products and imagining or predicting their use, it can be considered as an evaluation in the 'abstract interaction' type, one of the interaction types of Desmet and Hekkert (2007) . Since there was no clue about the brands and prices of the products whose images were shown to the user in the field study, the findings regarding the relationship between the symbolic information provided by the product appearance and the experience expectation were weak. Emotional impressions resulting from aesthetic and functional-ergonomic information have resulted in higher experience expectations.

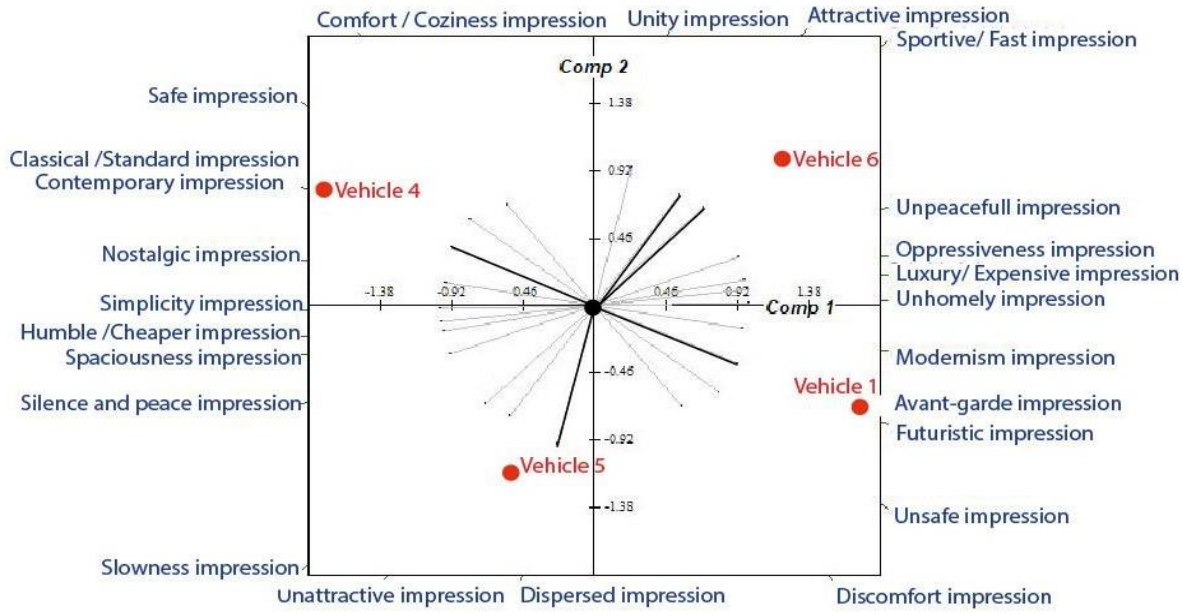

Figure 4. Principal Components Analysis of 6 elements

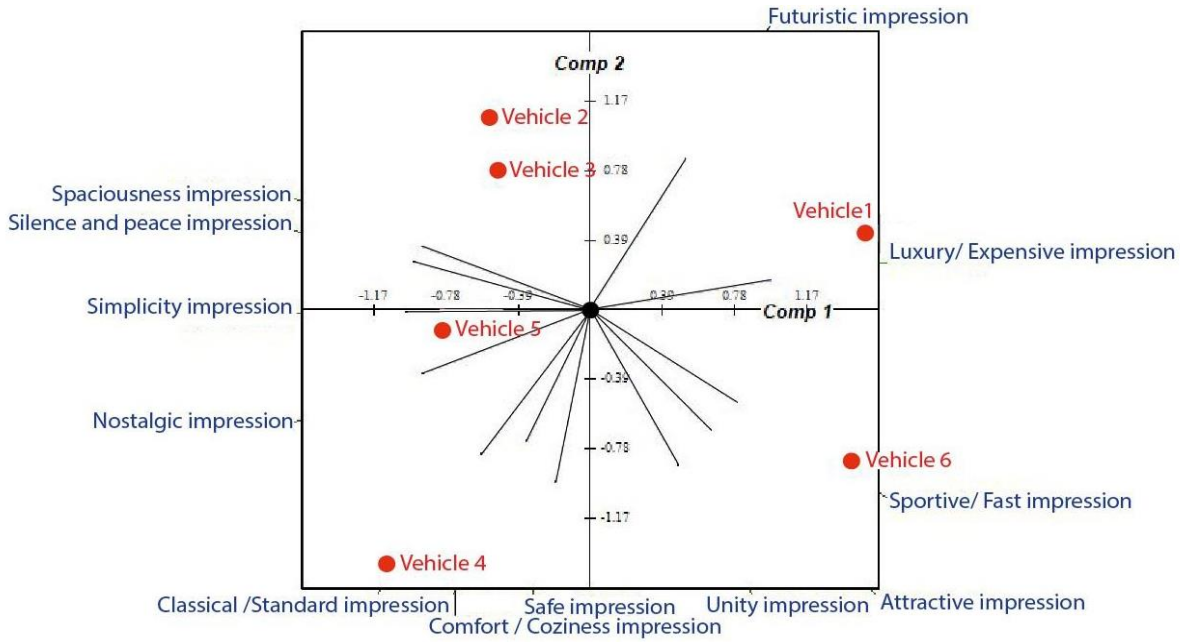

Figure 5. Key impression analysis for vehicles 1, 4,5 and 6

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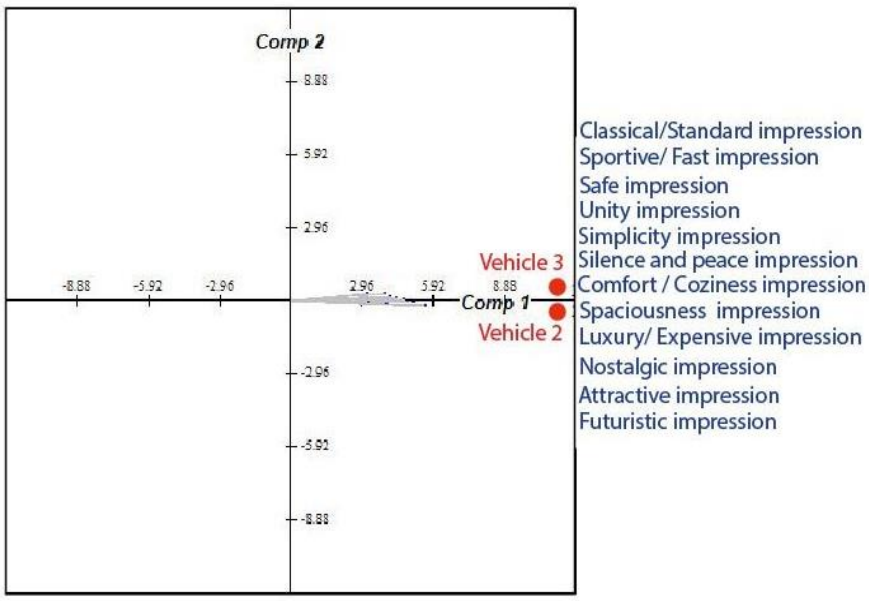

Figure 6. Key impression analysis for vehicles 2 and 3

4.3. Discussion

In this study, the employed method for measuring emotional impressions falls within the category of tools relying on participants' verbal expressions. The repertory grid technique used in the fieldwork is a method that facilitates visual product evaluation through the user's verbal expressions. Since users evaluate using their own expressions, it can be considered a subjective evaluation method. The user's prior experiences, personal and social background, and history can influence these expressions. However, Norman (2003) points out that no emotion measurement method can effectively address challenges arising from behavioural and emotional needs due to demographic changes.

Products convey aesthetic, functional, ergonomic, and symbolic information to users through their appearances. Users, in turn, exhibit cognitive, emotional, and behavioural responses to this information. Based on these responses, users demonstrate approaching or avoiding behaviours towards the products. Impressions and emotions always complement each other, relying on each other to establish a specific connection with the environment. Impressions shape emotions, forming positive or negative perspectives on them. Therefore, understanding the expected user experience perception based on the information conveyed through product appearances is valuable. This study examines the relationship between anticipated-user experience and product appearances, while also providing a research application method for other product categories. Designers and product developers can measure the anticipated-user experience perception by using methods that analytically express users' verbal expressions in the product development process. By making changes to product appearances, they can positively influence the perception of user experience.

The most significant contribution of our study is the identification of key impressions that can be related with the anticipated user-experience of a technology-driven new product. 74 key impressions are identified during the Repertory Grid Study. These key impressions contribute to the generation of an impression vocabulary in the context of automobile design. Moreover, these impressions are classified in 8 themes based on the similarities among them. These themes and key impression can be used to establish an evaluation basis for evaluation and or exploring the anticipated user-experience of a newly designed product. Our findings are parallel with findings of Yogasara et al. (2012), they key impressions as well as themes identified in our study are compatible with the Positive AUX and its sub parts: Pragmatic Positive AUX and Hedonic Positive AUX.

In this study, the collection of emotional impressions through the repertory grid, which includes users' verbal expressions beyond the models or evaluation methods found in the literature, has not constrained participants to a limited space and has allowed data to be collected across a broader spectrum. The study distinguishes itself from other user experience studies not by using limited methods commonly

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employed in user experience research but by employing the repertoire grid technique. In contrast to methods that require users to express specific emotions or mark them visually, this approach contributes to the literature by collecting data from a wider range (potentially from the user's own perspective).

5. Conclusion

The aim of this study was to explore the anticipated experience of high-technology product prototypes that are not commercially available in the market. Therefore, intended users are unable to use and evaluate these product prototypes. The only interaction between these product prototypes and their intended users is visual interaction. Fully-electric automobile prototypes, also called show cars, are a good example for this situation. These vehicles are generally showcased in international auto shows but visitors (intended users) are generally not allowed even to seat in these cars to visually inspect their interiors.

Therefore, this study attempted to understand the basic components of their anticipated user-experience by using visual stimuli. Visual stimuli are strongly related products' aesthetic qualities as well as with users' hedonic impressions.

As mentioned in the literature, the first interaction with the user begins from the moment the user sees the product. So the Visceral level is the level that must be overcome first. At this stage, the product appearance provides aesthetic, symbolic, functional and ergonomic information to the user. Expectations regarding user experience are formed in line with the way we feel about the product before using it and the information we can get from it. When asked about the emotional impressions of users in the field study, participants expressed their impressions by comparing them with other products. Product appearance is largely involved in cognitive responses, and the information obtained from appearance affects cognitive responses and judgments, and therefore expectations about the experience. Considering the aesthetic information, it can be said that there is a high expectation that the visual appeal of the general shape of the product will create pleasant experiences.

This study is the first part of a larger scale ongoing study which is focused on transferring the findings of this study to design specifications and testing these specifications with conceptual designs in the context of anticipated user-experience. The findings of this study will be used to develop design guidelines for designers, as an input to help them to establish a relationship between hedonic impressions and design elements in the case of electric automobiles. The authors are planning a further study aiming to use and test these guidelines in an experimental study with professional automobile designers from the industry. Also testing the effect of these design guidelines in the anticipated user-experience is another aim the planned study. Lastly, we recommend that a further and improved study must be done with a larger sample size with a narrower age range to explore deeper more detailed findings.

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