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CLASSIFICATION OF HUMAN–VEHICLE INTERACTION: USER PERSPECTIVES ON DESIGN

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With the advent of the Internet of Things, scientists expect that the relationship between humans and motor vehicles will become integrated with information and communications technology to a greater extent. We examined the developmental stages of human–vehicle interaction (HVI) in the automobile industry and the changes in the relationship between humans and the motor vehicle. In this study we have provided a set of guidelines that enables the designer to classify goods and services applicable to an automobile based on socio-behavioral evaluation. To support this, we analyzed driving tasks and conducted a focus group interview with 39 people to determine their inherent demands related to motor vehicles. We identified 3 stages of HVI: driver-centric, user-centric, and customer-centric.

Keywords: human–vehicle interaction, human-centered design, automated vehicle, driver behavior and expectations.

New generations of motor vehicles that are being released have increasingly complex technologies designed to offer increased safety, connectivity, and machine intelligence. The ability to operate these features intuitively is of key importance to achieving a more efficient, comfortable, enjoyable, and satisfying ride; thus, the installation of systems that facilitate human–vehicle interactions (HVIs) plays an important role in the commercial success of vehicles and must be factored into the development process (Marcus, 2004).

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Currently, the motor vehicle is being transformed into a more automated version; intelligent parking assistance, in-car Wi-Fi hotspots, and self-steering capabilities have all become commonplace in high-end cars (see, e.g., BMW Group, 2017; Mercedes-Benz TechCenter, 2016; Tesla Model S, 2017; Volvo, 2017). Computer software is becoming an increasingly important part of the vehicle and it will not be long before semiautonomous or autonomous vehicles become a reality (Anderson et al., 2016). For the driver to be able to utilize the complex functions of future vehicles fully in a way he or she would find perceptive and intuitive, HVI should be developed by incorporating the human perspective in every step of interaction design (Gkikas, 2013). *Human-centered* or *human-centric* design is an approach to developing interactive systems with the aim of enhancing the usability and usefulness of systems by focusing on the users, their needs, and their requirements, and by applying human factors/ergonomics, usability knowledge, and techniques (Akamatsu, Green, & Bengler, 2013; Kim et al., 2010; Park & Jeong, 2013).

Although there has been research conducted on the categorization of HVI issues and user-experience factors, such as safety, mobility, comfort, feedback, and connectivity, in most studies the focus has been either on the technological aspects or on evaluation of usability by experienced designers. On the other hand, taking a human-centric approach would ensure that the HVI categories and user-experience factors reflect a human perspective, and would require designers and researchers to learn directly from the people for whom they are designing. This would enable researchers to make sense of what they learn, to identify opportunities for design, and to develop a prototype with possible solutions that take human-centric approaches. The purpose of our research was to understand the views of user groups regarding the factors that comprise HVI.

There have been studies in which the researchers have attempted to categorize driving behavior by breaking down the task of driving into two or three categories. However, in their categorization of the task of driving, the researchers have focused on the functional aspect of driving; less attention has been given to the aspects of HVI, such as interaction method, driver distraction, alertness, driving style, control, and other dynamics. Here we ignored the perspective of concentrating on the driving task itself; instead our aim was to classify the integrated experiences that people encounter when driving a motor vehicle.

Literature Review

Human–Vehicle Interaction

Recently, the research on HVI has been expanded to include the behavior or preferences of drivers when they are in the vehicle. Studies in which researchers analyze drivers' behavior when in the vehicle can help in the identification of more intuitive interaction methods that are more naturalistic to, and preferred by, the drivers. For example, Wang and Ju (2015) found that drivers preferred to use a smartphone application (app) as their primary navigation tool and the in-vehicle navigation system as the secondary tool. Jeong et al. (2013) researched the preferred location for placing the whole display panel within the vehicle by using multiple physiological sensors.

Compared to previous research on HVI conducted from a human behavioral perspective, our aim was to improve on those previous studies in two main ways. First, unlike studies in which the researchers analyzed a specific interaction method or type of driver according to demographics such as age or gender, we took an integrated approach to classify HVI. For example, among the various HVI studies in which the focus has been on control methods, He, Bi, Lian, and Sun (2016) concentrated on a brain signal interaction method, and reported results that indicated the use of brain signals is feasible as an in-vehicle interface. Normark (2015) focused on touch as an interaction method, and reported finding that participants considered in-vehicle systems to be useful if they were personalized. Vernon et al. (2015) carried out a study with drivers aged over 65 years and found that the use of electronic devices increased the risk of a crash or near-crash. In the present study, however, we considered drivers' experiences, requirements, values, and behaviors and the ergonomics of driving a vehicle.

Second, compared to previous studies in which researchers limited the scope to the expectations of drivers, in the current study we determined the latent needs of both drivers with no expertise in the fields of science, technology, engineering, arts, or mathematics and of people working in a relevant field with a doctorate in either engineering or design, who outlined realistic approaches.

Task of Driving

Driving is a complex activity that requires multitasking and both driving and nondriving skills (Regan, Lee, & Young, 2009). Driving behavior has been categorized into three tasks: primary, secondary, and tertiary (Di Salvo, Gaiardo, & Giuliano, 2015; Tonnis, Broy, & Klinker, 2006). The primary driving task involves direct control over the vehicle's movement, including longitudinal and lateral control (Loehmann & Hausen, 2014). The secondary driving task includes assisted driving-related activities, that is, tasks that enhance driving efficiency but do not directly influence vehicle movement (Harvey, Stanton, Pickering, McDonald, & Zheng, 2011). Tertiary driving tasks include nondriving-related infotainment activities that may enhance the driver's experience, such as listening to music or making a phone call (Tonnis et al., 2006).

As vehicles have become increasingly automated over time, the task of driving itself has also evolved (Loehmann & Hausen, 2014). Pfleging and Schmidt (2015) have argued that driving should be divided into two tasks: driving-related and nondriving-related activities. Likewise, in the current study our aim was to identify and categorize the pattern of driving tasks to determine the ways in which the task pattern changes as the vehicle becomes more automated. Among ways of categorizing the levels of automation in a vehicle, we conducted interviews with two determined levels, that is, human driving level and automated driving level. Here, *human driving level* refers to the level where the human driver monitors the driving environment, and *automated driving level* refers to the level where an automated driving system monitors the driving environment (Smith, 2013). Unlike the US National Highway Traffic Safety Administration, SAE international, or the German Federal Highway Research Institute, where the automation is categorized into five or six levels, we bisected the level into two levels, as it has been found that the participants, particularly the ones without experience and/or knowledge in the fields of science, technology, engineering, arts, or mathematics, tend to experience difficulties in differentiating three or more levels. Our research differs from that of previous studies in that the focus was on the driving task itself. We also investigated driving behavior in terms of drivers' interactions with the vehicle. Rather than using a research-based methodology to establish trends, we used a qualitative method and conducted focus group interviews to establish the values of these two groups: the first composed of individuals who did not have a background in a science, technology, engineering, arts, or mathematics area, and the second composed of individuals with a doctorate in either engineering or design.

Method

Participants

We conducted focus group interviews with 39 people, of whom 18 were individuals who did not have a background in the areas of science, technology, engineering, arts, or mathematics, and 21 people with a doctorate in either engineering or design. The average age of participants was 31.9 years (*SD* = 6.38); 17 were men and 22 were women. On average, the participants had 10.2 years (*SD* = 6.11) of driving experience. In Table 1 the demographic information of the participants is set out.

Procedure

In the focus group interviews our aim was to survey qualitatively and analyze the participants' understanding of HVI. Focus group interviews have been a very popular tool used by researchers for determining marketing or business trends for more than 30 years, and are recognized as a recommended research method when conducting the initial stage of a study (Gray-Vickery 1993; McKinley, Manku-Scott, Hastings, French, & Baker, 1997; Ritchie, Lewis, Nicholls, & Ormston, 2013). The interviews are informal discussions undertaken by a group consisting of a small number of people selected for a specified topic in relation to a specific situation. This approach helps elicit emotions and reveal the attitudes and values of the interviewees (Vaughn, Schumm, & Sinagub, 2012). Taking part in the group may improve or change participants' opinions on a specific topic. The focus group interview is useful for generating data to analyze participants' patterns, behaviors, and personalities as it enables interactions among the participants and between the researchers and participants (Kitzinger, 1995).

Table 1. *Focus Group Participants*

Question	Category		Frequency
Group (participants)	Users	Workers	7
		Students	6
		Housewives	5
	Professionals	Engineers	10
		Designers	11
Age (years)	Average 31.9 (± 2.5)		
Gender (participants)	Male		17
	Female		22
Driving experience (years)	Average 10.2 (± 2.5)		
Frequency of driving (times)	Almost never		8
	Once a week		10
	Twice or thrice a week		6
	Almost every day		15

The data from our focus groups were analyzed using the KJ Method, or the affinity diagram method, which is a data analysis method developed in the 1960s by Jiro Kawakita as one of seven management and planning tools for total quality control (Kawakita, 1982). It is a bottom-up creative problem-solving methodology that involves divergent and convergent thinking steps to generate specific themes from unstructured information on a subject (Kunifuji, 2013). It is recognized as particularly efficient and useful for investigating a new concept or field instead of verifying a thesis or hypothesis (Scupin, 1997). One of the most notable aspects of the KJ Method is how effectively it objectively leads groups to the top priorities. Different groups can analyze the same data and often reach the same conclusions (Moggridge, 2007). In the context of our study the combination of the focus group interviews and the KJ Method enabled participants to share their opinions, expectations, and creative ideas about future driving environments during group discussions (Krueger & Casey, 2000).

The five main stages of the KJ Method are (a) label making, (b) label grouping, (c) group naming, (d) chart making, and (e) written or verbal explanation. In our study participants' statements, opinions, and ideas were sorted and grouped to construct an affinity diagram, thereby allowing the researchers to determine the relationships between groups of responses. In this study, we conducted five focus group interviews (see Table 1). Here, three groups (workers, students, and housewives) were the user groups without professional qualifications in the science, technology, engineering, arts, or mathematics areas. The other two groups were people with doctoral degrees in engineering and design.

Measurement and Data Analysis

Each of the focus group interviews took from 50 to 60 minutes, which was divided into four stages (see Table 2). The first stage was the warm-up stage: the moderator interacted with participants to encourage a friendly and positive environment throughout the interview. In this initial stage, a brief introduction to the interview topic was provided and the participants were requested to sign a form agreeing to take part in the interview. The consent form included our institution's code of ethics for research involving human subjects. Interviewees were encouraged to share their honest opinions and thoughts openly by informing them that there were no right or wrong answers, and that all their experiences, opinions, and thoughts were valued. The second stage was a bridging stage: participants were questioned about their driving behavior and were asked to answer questions about their driving experiences. The third stage was the main stage: participants responded to in-depth questions about their driving behavior, interactions, creative solutions for aspects of driving, and future expectations of driving. The fourth stage was the closing stage in which the moderators expressed their appreciation for the interviewees' contributions and provided gift vouchers worth approximately US$10 to thank them for their participation.

Table 2. *Focus Group Interview Questionnaire*

Interview Stages	Contents	
Warming-up Stage	• Ice-breaking questions • Introduction about the interview	
Bridging Stage	• Which of the car's functions do you use while driving? • What other devices do you use while driving?	
Main Stage	General	• What do you think is the most crucial element of a vehicle?
	Present	• Which factors do you find uncomfortable while driving the vehicle? Why do you find them uncomfortable? • Are there any functionalities you wish were available? Why do you need them and how would you interact with those functionalities?
	Future	• Imagine that you are driving an automated vehicle. What would you do in the vehicle? How would you interact with the vehicle? • Is there another promising function that you expect to have in a future vehicle?
Ending Stage	• Appreciation for participation	

All the interviews for this study were recorded on video and transcribed verbatim as agreed upon in the informed consent form that the participants had signed previously. The researchers transcribed the comments and opinions they judged to be meaningful by writing each comment or idea on a separate Post-it note. These notes were then spread out on a table so that every comment was visible to the researchers. Through brainstorming, the researchers reached a consensus by diverging the comments and ideas provided by each group and then converging correlating comments through label grouping until all of the researchers agreed. To carry out this regrouping process we considered behavioral factors, environmental factors, timing, and factors that the participants valued.

Results

Each of the nine items we selected (mobility, safety, control, input interaction method, feedback, customization, infotainment, telematics, and connectivity) contained interviewees' comments regarding interactions directly related to maneuvering a vehicle, interactions with vehicle interfaces, or interactions the participants envisioned performing in a future autonomous vehicle. Consequently, the items were classified into three categories: driver-, user-, and customer-centric HVIs. The resulting chart is shown in Figure 1.

Driver-Centric HVI

In the data pertaining to driver-centric HVI, participants focused on concerns about the future driving environment and their comments could largely be categorized under three main headings: safety, mobility, and control.

Mobility. The primary purpose of driving a car is mobility; that is, traveling in an automobile enables a person to reach his or her destination by the fastest route through popular and personal transportation. All the participants agreed that most of their behavior while driving the vehicle was fundamentally focused on mobility issues, such as using the steering wheel (lateral movement) and the accelerator or brake pedals (longitudinal movement). They were all of the opinion that they would not expect the purpose of using a vehicle to change, regardless of time or place. For instance, most of the user group consisting of workers and housewives strongly contended that even if vehicle technology was to become so advanced that automobiles become highly or fully automated, it would still be necessary for information relating to mobility to be provided within the vehicle, such as the speed at which it is traveling, its location, and the amount of time remaining until the destination is reached.

Safety. The major issue raised by all five groups was safety. Although the primary purpose of driving a motor vehicle is to travel to a destination, the task that had highest priority was to drive safely. Indeed, various measures have been implemented and research has been conducted to improve road safety, such as mandatory seat belt usage, stricter penalties for drunk driving, and lowering speed limits (Hancock, Parasuraman, & Byrne, 1996). Participants' perceptions about safety were either pessimistic or optimistic with regard to HVI. Participants who were pessimistic emphasized concerns about malfunctioning technology, whereas the optimistic participants expected improved technology to mean enhanced road safety. On this point the user-experience designers recommended the necessity of introducing innovative technologies gradually, moving to the next stage of automation only after building driver trust through the use of less-automated technology. For instance, only when drivers were assured that the alerting role of advanced driver assistance systems, such as adaptive cruise control and lane departure warning systems, are efficient, would such systems be able to proceed to the next stage of automation in the form of automatic control over lateral or longitudinal movement. Participants agreed that improved road safety should be ensured for both the passengers inside the vehicle and the pedestrians or other road users outside the vehicle.

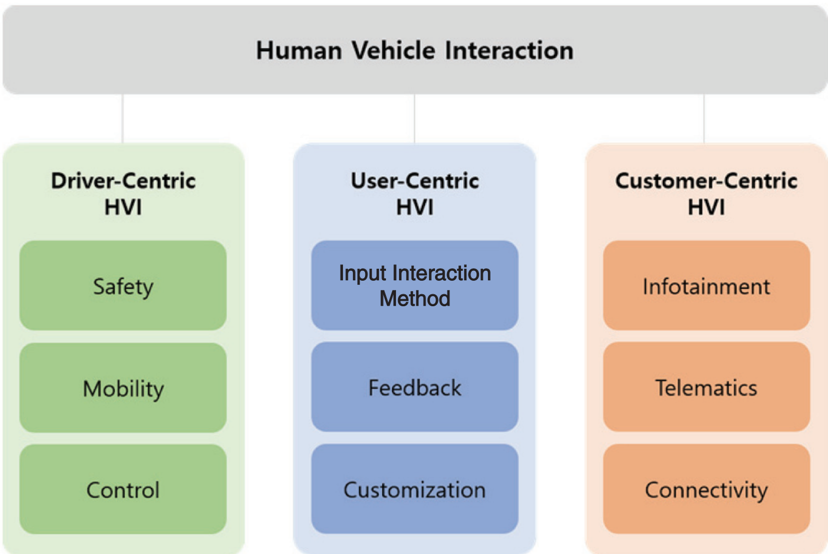

Figure 1. Focus group interview results.

Control. The two types of control while driving a motor vehicle are control over the known and control over the unknown. Participants who said they liked to have control over the known said they enjoyed driving and did not want a vehicle that would deprive them of the joy of doing this. Some participants told us that their main reason for driving was to enjoy the driving activity itself. In this regard, designers agreed that it is necessary for them to consider which functions should be automated and to what extent, and they suggested that a transition phase between the human and automated modes could be implemented. Control over the unknown was related to the safety issue. Engineers commented that being in control of the car provides stability, and that countermeasures should be in place in case of an emergency even in the environment where the vehicle drives by itself, so that drivers feel secure even if they are not monitoring the driving environment.

User-Centric HVI

Participants' concerns about user-centric HVI were categorized into three groups: input interaction method, feedback, and customization.

Input interaction method. Participants had experienced difficulty with various interactions while driving, particularly when changing radio channels, receiving phone calls, and looking at the navigation display. Interviewees shared their opinions about voice recognition as a future interaction method. They found this form of interaction to be effective and intuitive, and they wanted to eliminate any obstacles that restrict their driving behavior. However, because the voice recognition system in the vehicle could respond to words unintentionally spoken by the driver or passenger, they recommend that a feedforward system should be installed to act like a safety lever.

Feedback. Receiving feedback was another crucial aspect of HVI raised in the interview. Haptic, or tactile, feedback such as feeling vibration on the car seat or force on the steering wheel, and visual feedback were described by all as being efficient, along with the audio feedback currently provided in automobiles in the postmodern era. Haptic feedback, which enables people to distinguish physically between changes in the system of an automated car, was considered by workers and two designers as safe and easy to understand. With regard to visual feedback, one of the workers and three designers suggested changing the color in which important information, such as speed, is displayed, as this can be a hedonic, intuitive, and effective method to provide relevant information to the driver. A head-up display, that is, a transparent display placed on the windshield so that a driver can simply move his or her head up to access the information, was also discussed by a worker, three students and all of the designer and engineers' group as an effective method for interacting with information displayed in the automated vehicle, such as its speed or destination, provided that it does not excessively obstruct the view the driver has of the road in front of the vehicle.

Customization. Participants in the design and engineering groups also said that the functions of an automated car should be customizable for efficiency and convenience for the owner. Furthermore, interviewees in both the professional designer and engineering groups agreed that such a customizable function should include easy switching between the automated and human modes of driving. Most participants attached great importance to being able to customize their personal settings.

Customer-Centric HVI

All participants mentioned customer-centric aspects of driving when discussing their future expectations about autonomous motor vehicles. For instance, in their responses as to their preferences regarding vehicles in the future, the types of services or content they would enjoy having available to them were highlighted, these comprising infotainment, telematics, and connectivity.

Infotainment. The term *infotainment* is a blend of entertainment and information. Infotainment services that can be provided within a vehicle include systems for playing audio content, for utilizing a navigation system for driving, and for delivering rear-seat entertainment (Harper, Rodden, Rogers, & Sellen, 2008). Nearly half of the participants' opinions involved services they expected in the future. Most of the participants desired Internet-based entertainment services, such as reading online magazines, watching movies or television, and listening to music. This suggests that people expect to minimize driving-related tasks, while focusing on more entertainment-related activities in the future autonomous driving environment.

Telematics. The term *telematics* refers to telecommunications and informatics, both of which would be under the control of the vehicle (Harper et al., 2008). Tasks concerning location information, finance, product purchases, and reservations can be performed with in-vehicle telematics service systems. The majority of participants indicated that they looked forward to telematics as a future in-vehicle service, along with navigation and medical services, such as monitoring of temperature and heart rate. Alongside humans' need for communication, drivers generally had great expectations of this aspect of HVI.

Connectivity. People are now living in a more socially connected world, regardless of distance or timeframe (Harper et al., 2008). Participants commented that motor vehicle connectivity includes vehicle-to-everything, vehicle-to-vehicle, vehicle-to-nomadic devices, and vehicle-to-infrastructure connectivity. Through connectivity, participants expected a highly automated and well-informed future lifestyle in their motor vehicles. They suggested that connectivity in the society of the future would not be limited just to connectivity among humans, but would be extended to include connectivity of humans, devices, objects, and the environment the person is in. As the motor vehicle becomes a second private space for the individual, it should be capable of functioning as a platform where drivers and passengers can access all the information that surrounds them.

Discussion

The data we collected on driver-centric HVI revealed the participants' perception of essential prerequisites for future autonomous cars. These prerequisites included mobility, safety, and control. Among these three driving tasks the primary focus has been either on mobility (Loehmann & Hausen, 2014; Tonnis et al., 2006) or on mobility and safety (Pfleging & Schmidt, 2015). Similarly, participants in our study valued HVI related to mobility and safety. However, our participants also considered control over the vehicle a significant factor in both human and automated driving environments. For some participants, the control aspect was related to their concerns over the extent to which technology can be trusted; for others, control was a factor that motivated them to drive a vehicle.

Regarding user-centric HVI, participants generally expressed opinions about intuitive or seamless interaction methods. Through changes in interaction methods, they expect to have more intuitive control over motor vehicles of the future. Regardless of driving- or nondriving-related activities in the vehicle, participants expressed great interest in interactive systems that are intuitive and that perform efficiently and effectively.

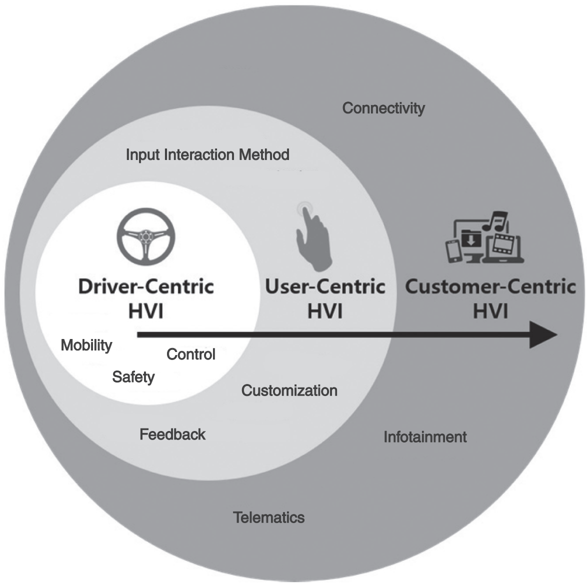

Figure 2. Summary of the relationship of the three types of human-vehicle interaction.

According to participants' discussions, the customer-centric HVI could be considered an eventual HVI that drivers would like to enjoy in their autonomous car of the future. The aim of customer-centric HVI is to shape usable, desirable, useful, efficient, and effective HVI services that suit customers' preferences and lifestyles (Moritz, 2005), so that the vehicle functions as a private space from which customers can purchase various goods and services. This concept transcends the notion of the car as a simple tool for mobility and makes it an interface between customers and the outside world.

This suggests that designers should approach human-centric HVI strategically, in order to fulfill driver-, user-, and customer-centric HVI demands sequentially (see Figure 2). According to our results, driver-centric demands must be met before proceeding to the larger stage of user-centric HVI as customer-centric HVI can only be enjoyed with appropriate user-centric HVI.

In the current study, we classified human-centered HVI into three categories: driver-centric, user-centric, and customer-centric. Our analysis of focus group interviews revealed that the participants' main expectation for future autonomous automobiles is the provision of services (customer-centric design). To achieve this ultimate goal, however, driver- and user-centric HVI should be fulfilled first. If the autonomous car is proven to be safe and mobile, and has intuitive interfaces installed, only then would people be able to enjoy the enhanced services that an autonomous vehicle offers.

Compared to previous studies, in this research we adopted an integrated approach to determine the requirements, needs, and values of drivers. By conducting a study with both people with no technical or science background and with qualified engineers and designers, our findings in the study provide guidance that takes both latent needs and realistic possibilities into account. Therefore, our study is significant because our findings provide guidelines for automotive and related industries, and the factors that should be considered with regard to HVI are outlined from a behavioral perspective. Our research is also an effective analysis based on each of the categorizations of HVI.

As with all qualitative research, there is a limitation in terms of generalizing the results. In this regard, the findings can be verified by scholars undertaking quantitative research in the future. Additionally, we would like to investigate and design the specific services people expect to enjoy in an autonomous automobile by considering customer-centric HVI as the central value.

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