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The New Interaction Mode of Human-Vehicle in Automatic Driving: Overview of the Reification-Perception Interaction

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ABSTRACT

Under automatic driving, the driver and the vehicle systems control the vehicle together, interface interaction is no longer the main form of human-vehicle interaction. The new interactive form based on the reification-perception of the vehicle interior through the technology cluster emerge. The Intelligent Interior is capable to perceive the user and then makes the feedback close to the prior experience of users. Based on the review of the characteristics of human-vehicle interaction in the Intelligent Interior of the vehicle, this paper named human-vehicle interaction as Reification-perception interaction (RPI), and summarizes the current trend characteristics of human-vehicle interaction. Current study suggests that the RPI could be the new form of human-vehicle interaction formed by the cross-fusion of multiple interactions (Whole-Body interaction; Natural Interaction; Entity interaction). This paper proposes the relationship and structure mode of RPI which provides an appropriate and novel research direction for the human-vehicle future study.

Keywords: Reification-perception interaction, Pre-empt perception, Entity interaction, Whole-body interaction

INTRODUCTION

The interaction between humans and vehicles has changed as a result of the development of autonomous driving technologies. There are now more than simply the two roles of user and vehicle in the Human-Vehicle Interaction (HVI). The human-vehicle relationship has become considerably richer with the advent of Intelligent Vehicle Systems, and there is a significant difference from the traditional human-vehicle interaction. The driver's job will no longer be restricted to dynamic driving as autonomous driving technology has now advanced to the stage of car-machine assisted driving (A. Herrmann et al. 2018). The deployment of an intelligent vehicle system will help drivers and free up their hands, but it will also increase the user's demand for non-driving behavior (L. Yang et al. 2021). The ergonomics that apply to conventional vehicle interior design are no longer the only criteria, and a new benchmark is required to assess and direct vehicle interior design in the context of autonomous driving.

This paper defines HVI as Reification-Perception Interaction (PRI), elaborates on the fundamental idea of Reification-Perception and the motivations behind its invention, outlines the current trends and characteristics of the development of HVI, and on this foundation proposes the new idea of "Cognitive Center of Gravity." The new concept of "Cognitive Center of Gravity" is proposed, which provides a suitable and novel research direction for the future research of human-vehicle relationship.

REIFICATION-PERCEPTION INTERRACTION

Basic Concepts of Reification-Perception Interaction

With the development of the vehicle Intelligent Interior level, the data characterization level and scope of the interior have greatly expanded. Data now has a personal presence because everything about "Object" in automobile interiors is entirely digitalized and data has been given the power to attach to items. For instance, a vehicle interior can proactively sense the user's state information and adapt the interior's condition accordingly (active braking, volume adjustment, etc.) based on its surroundings. On the other side, a user can be identified by their physical characteristics (such as biological monitoring, eye movements, other physiological traits, and even emotional computing), which gives them a digital presence and gives digital information "human being" attributes.

"Reification" is generally defined as "a relationship between people taking on the nature of a thing." According to (Timo Jütten, 2010), the term "Reification" has three degrees of interpretation. Reification first relates to the idea that individuals are treated as things; second, it denotes the idea that people modify their relationships with others through objects; and third, it denotes the traits of related objects in a social system. User engagement with vehicles is still the focus of this article. However, the user's behavior and state are perceived and represented by the technology cluster. It can be considered that two aspects of transformation between Intelligent Interior (object) and users (people), one is the digitalization of objects (or people), the other is the reification (personification) of data. The relationship between human and Intelligent Interior systems is adjusted through the digitalization of people. In this sense, the HVI in the Intelligent Interior shows the characteristics of "Reification".

Reasons for the Creation of Reification-Perception Interaction

The so-called Ergonomics can be considered as the designer's study of the human-machine layout prior to the development of the Intelligent Interior idea. The primary driving task of the driver is facilitated by the ergonomic interior design of the vehicle. The display made its way into the vehicle interior, which led to an increase in the complexity of the HVI. There are lots of additional jobs in vehicle interior, the major interaction behavior is focused on the display and the main driving area. Therefore, the HVI was defined as human-computer interface interaction in that moment (K. Bimbraw, 2015). With the advent of multi-modal and multi-channel interactive and the widespread adoption of automated driving and intelligent interiors, users of vehicle interiors are no longer restricted to interacting with displays. This frees up the user's hands, shifting the cognitive load from the primary driving task to the secondary driving task. As a result, even though vehicle ergonomics established the fundamentals of HVI, it is now unable to characterize the form of HVI.

The term "Space" was coined by architects (Wang Zhengtong et al. 2020), and vehicle interiors are comparable to architectural space. Because of the limitation of the vehicle interior space, the function of the interior space needs to be more specific. Before the advent of self-driving, vehicle designers structured interior aesthetics around the principal driving activity. Because of the ergonomics limitation and the engineering structure of the automobile itself, the vehicle design generally may be characterized as the manifestation of ergonomics, and the vehicle interior users can only be defined as a car driver. When cars enter the age of self-driving, interior users will be able to remove their hands from the steering wheel with the assistance of an Intelligent Interior; the user's cognition becomes redundant, and attention turns to secondary duties (Joost C.F. de Winter et al. 2014). Therefore, interior designers have evolved from driver-centered design to interior design as scene design or service design; sub-driving tasks and tasks represent the definition of scene characteristic. The inclination for several driving tasks to use ergonomics as a framework to fill the inside space is a vehicle interior property.

Support for secondary tasks is a consequence of the development of autonomous driving (A. K. Huemer and M. Vollrath, 2011). With the innovation of autonomous driving technology and the development of multimodal, multichannel interaction technology, the focus of interior design will gradually shift to secondary tasks other than driving, and the focus of interior design will shift from the driver to the entire driving scenario in the vehicle. This study provides a schematic diagram of the RPI development structure in response to this status and trend (Figure 1). In the context of intelligence,

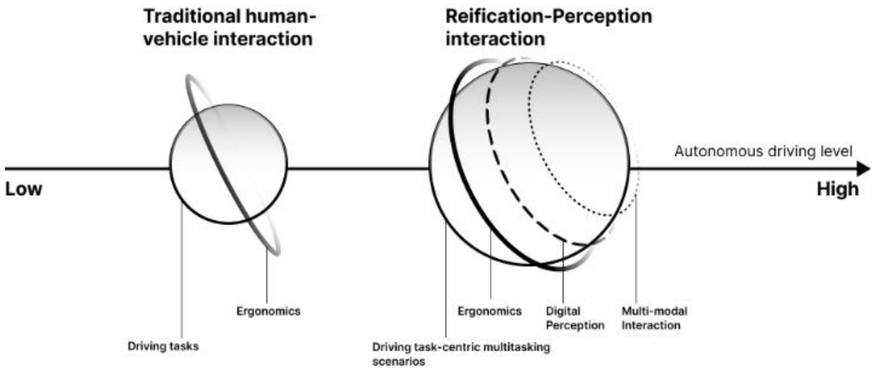

Figure 1: Human-vehicle RPI structure (draw by author).

RPI is a more complex category and its structure is based on automotive ergonomics, with driving tasks in the car as the primary task and task scenarios containing multiple secondary tasks as the core, including multimodal interaction and digital perception, as well as other characteristics of user behavior performance.

THE CHARACTERISTICS OF RPI: FUSION DESIGN OF MULTI-INTERACTIVE FORM

Naturalization of In-Vehicle Interaction

Since the introduction of the automobile, there has been continuous interaction between humans and vehicles. As time progresses and technology advances, the method of interaction within vehicle interiors is continuously modernized. The effectiveness of information transfer between humans as "Object" and the automobile has been a fundamental concern in automotive interaction. Researchers have developed the idea of "interaction naturalization" in order to properly capture the user's subjective experience of efficient information production and sharing.

Interaction Quality is the universal, objective and unbiased effectiveness of HMI (A. Schmitt et al. 2011). And one of the criteria for measuring the interaction quality of intelligent vehicles is the naturalness of interaction (Z. Tan et al. 2022). The greater the interaction quality, the closer the interaction behavior is to the human instinctual response, the more natural the interaction behavior, and the closer the interaction behavior is to the human instinctive response (Y. Shi, 2018). Therefore, the most direct way to improve the interaction quality is to minimize the input and output costs of the interaction information, while making the interaction relationship between the two more consistent with the user's a priori knowledge and mental model, so that the user and the car can perceive each other's intentions more naturally and with less load. The research on the sense of natural interaction quality in the interior cannot be isolated from the research on the cognitive model and process of the user, according to this viewpoint.

With the advancement of technology, the interaction quality of vehicle interiors is gradually increasing, and the user's behavior in the vehicle is completely dataized by the vehicle system, thereby enhancing the vehicle system's perception of user information and the user's interaction behavior with the interiors. The gradual introduction of multimodal perception and physiological detection technologies for vehicle interiors (T. Nakagawa et al., 2017) has made the interaction between users in the car and the vehicle system in the past more robust. In the mechanical interaction stage, the user can only operate the vehicle's interior via its limbs (levers, physical operation knobs, etc.), and the interior can then perceive the owner's information and provide feedback. During the interaction procedure, the user releases information through various body parts in order for the inside of the vehicle to provide feedback. Perceptions of user information within the vehicle interior lag behind. Currently, in the Intelligent Interior, a variety of input channels (microphone, camera, touch screen, etc.) are integrated to sense the user's behavior (eye movements, gestures, etc.) and physiological indicators (heartbeat, body temperature, etc.), which are transformed into data for input into the vehicle system, so that the user need not actively send information to the vehicle, but the vehicle actively uses sensing technology to obtain information (G. Wiegand et al. 2019). This considerably aids the establishment of normalized human-vehicle interaction. Moreover, research on anticipating human intentions is already underway, and car systems can potentially anticipate user behaviors and respond to them in advance using deep learning (B. I. Ahmad et al. 2017).

The essence of interaction naturalization is facilitating the seamless transfer of the user's existing knowledge and cognitive model to the understanding of the new interaction behavior (Valli A., 2008). Combining the historical evolution of car interiors reveals that the HVI design approaches the user's deeper cognitive level via the natural interaction concept and technology cluster. The "Purpose in action" of the vehicle interior is closer to the user's prior intention, allowing them to accomplish engaging activities with reduced time cost and cognitive burden (Turner P., 2008).

Entity Interaction

The conventional HVI consists of a significant number of physically interactive components (Zhang Jing, 2017), which are responsible for control and display. As automobiles transition to low-level Automated Driving, traditional buttons are generally abolished and replaced by touch-sensitive virtual buttons, with a substantial number buried beneath the screen. Nevertheless, as evidenced by the retention of Tesla's grill, the vehicle interior users' physical operating demands have not lessened despite the absence of many physical components (Millar. G, 2018). It is owing to the user's prior expertise and skill in dealing with the inside of a standard non-Intelligent Interior-equipped vehicles.

With the advancement of material technology, the interior solid components (steering wheel, IP, etc.) have evolved from automobile ergonomics artifacts to solid components with interaction properties. Intelligent surfaces, physical feedback, tactile stimulation, and other interaction technologies at the manufacturing level transform mechanical contact into natural interaction behavior. Its essence is the entity interaction concept of receiving feedback from actual action, which is consistent with the users' past knowledge and proficiency with the conventional vehicle interior. Mercedes-Benz, Baiteng, BMW, and numerous more automobile manufacturers revealed their visions of future entity interaction at CES 2020. The new design's sensory shape promotes the user's natural operation behavior and decreases the user's learning cognitive load.

From Embodied Interaction to Whole Body Interaction

In a broad sense, there are numerous ways in which humans and objects while they undergo ongoing evolution. Since the 1970s, new types of interaction have evolved as the academic community has started to question conventional graphical interface interactions. Users should utilize their human space talents to the most extent possible while interacting, according to these new interaction paradigms. For instance, in embodied interaction, people should use their bodies as essential tools and media to sense the physical world and carry out interaction activities (Svanaes D. and Young W., 2011).

The traditional graphic interface interaction concept, which emphasizes that "the body is the brain," is broken by the appearance of embodied design. According to the concept of embodied interaction, cognition resides in the human brain, the body, and the physical world; these three components link and resolve issues. Dourish (Dourish P, 2001) and Streeck (Streeck J et al. 2011) made a point about embodied interaction; they hold that the human body is the critical tool for the user to perceive the physical world during embodied interaction. Additionally, the machine need to be an extension of the human body rather than just something that exists outside of it.

Embodied interaction underlines the constraints of learning cognition through physical contact. First and foremost, bodily sensation is a prerequisite for embodied interaction. Users occasionally may receive incorrect information from the outside, which causes them to receive inaccurate feedback from the vehicle's interior. Second, embodied interaction emphasizes sensory processing of the external world, but ignore the elements from the inner world of human, just like visual abstraction, user emotion, physiological function. Instead of focusing on a person's internal processes, embodied contact emphasizes the body's external performance.

Whole-body interaction is a new field in the interaction of automotive interiors, which was first proposed by Buxton (1987). According to England (England, David et al., 2009), whole-body interaction was the collection of all signals in 2009 (physical, mental, cognitive, emotional, etc). Human states, such as cognitive load (Y. Liang et al. 2007), subtask (M. Muoz et al. 2016), emotion (X. Wang et al. 2019), location (Y. Xing et al. 2018), tiredness (K. Li et al. 2020), etc., can be identified and collected by the system. Digital technology is used to incorporate the captured feedback into the digital realm, which is subsequently transmitted back into the physical space and perceived by the user. Consequently, whole-body interaction can incorporate data from exterior and internal actions. In this regard, embodied design is a unique sort of whole-body engagement. For instance, fatigue driving detection is a basic automobile interior interaction technology. During driving, the interior must be able to identify the driver's physiological status. Driver fatigue detection involves monitoring the user's eye movement frequency, human pulse, or body posture as an output with a statement of purpose (Deng Sanpeng et al. 2010). Different bodily positions convey distinct meanings in various settings. Consequently, while integrating user information, vehicle interiors necessitate both general interaction design thinking and numerous specialized interaction thinking in relation to the design process outlined previously.

With the advent of automated driving and intelligent interior, consumers are now able to dedicate more energy to non-driving duties. Cognitive load has become a prominent topic of study on RPI, both for driving tasks such as driving distractions (Sajad Ahmad Najar and Premjit Khanganba Sanjram, 2021) and for behavioral research beyond driving.

DISCUSSION

Basic Concept of RPI

RPI senses and transmits information utilizing digital technology, and this digital technology-based contact with HVI is more natural than ever. In the phase of interior design, human behavior is considered the primary component of interior perception and design. In conclusion, the user's interior activity results in digital information input to the vehicle system, which then provides feedback to the user via digital information output to various actuation units in the vehicle (screen, audio, smart surfaces, etc). As seen in Figure 2, the interior of the vehicle effortlessly communicates digital behavioral data between the user and the vehicle via multimodal information sensors and. The information is subsequently conveyed to the user via the guidance of the actuation unit, enabling the user to engage in more natural interaction behaviors.

Cognitive Center of Gravity

Driving an automobile is a tremendously difficult task (W. Wang et al., 2020), requiring three layers of planning and the processing of about 1600 separate tasks. A huge number of secondary and tertiary activities beyond the driving task have evolved in the vehicle as the level of autonomous driving rises. This tendency has led to a polarization of existing interior designs for autonomous driving. On the one hand, extremely sophisticated self-driving interiors assume too many primary driving functions, causing the driver to lose concentration. Studies have shown that vehicle automation impairs brain load (M. R. Endsley, 1999) and situational awareness (N. A. Stanton and M. S. Young, 2005) and that reaction times increase with increasing levels of automation (Llaneras, R. E. et al. 2013). When the vehicle wants the user to take over driving, it cannot do so in a timely manner due to the low brain load. On the other hand, an excessive number of secondary and tertiary responsibilities make the interior of the smart cockpit more complicated than before. The complexity increases the user's need for functionality and emotion; this contradicts the design philosophy of human-vehicle RPI.

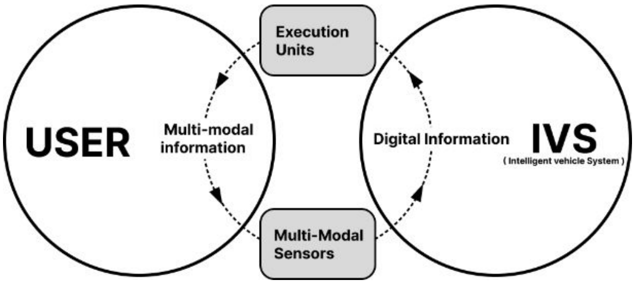

Figure 2: Interactive mode of vehicle interior under RPI (draw by author).

Through study on the developmental aspects of RPI, it is also clear that the ultimate goal of interaction naturalization, Entity Interaction, and embodied interaction research is to minimize the cognitive load of the user. Recent studies have demonstrated, however, that too little cognitive load while driving might result in driver distractions and slow reaction times (T. J. Gordon and M. Lidberg, 2015). This is due to the low cognitive load of the driver while driving, which results in focusing all attention on secondary tasks unrelated to driving, making it a transition period for the driver to recover during driving when control of the vehicle is transferred from the vehicle system to the driver (A. Eriksson and N. A. Stanton, 2017), making it difficult for the driver to regain situational awareness when the driver is not yet actively involved in the driving process (H. E. B. Russell et al. 2016).

Too much cognitive load causes anxiety and reduces the driver's state, while too little cognitive load causes distraction and prolongs the driver's takeover driving and reaction time, hence increasing road safety risks. Based on the aforementioned issues, this research provides a model of interaction behavior dubbed "Cognitive Center of Gravity" (see Figure 3). For the purposes of this work, Cognitive Center of Gravity, as one of the main parameters for measuring the quality of RPI, can be one of the important future research directions before the deployment of completely autonomous driving technology.

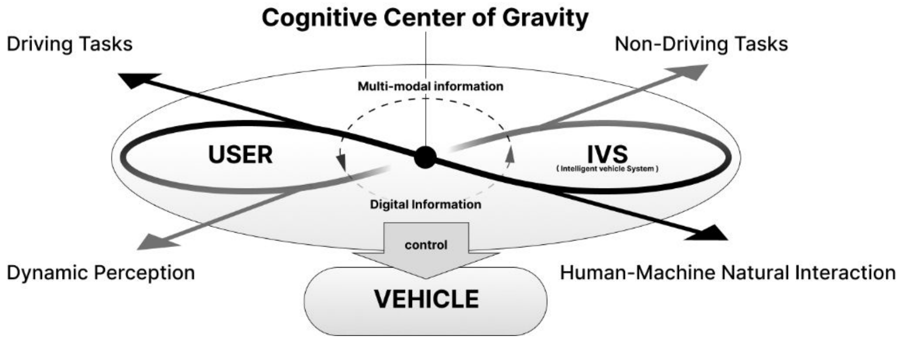

Figure 3: The relationship between the cognitive center of gravity and automobile interior under RPI (draw by author).

CONCLUSION

This study presents a concept of interaction in vehicle interiors and describes a novel model of human-vehicle interaction in smart automobiles based on RPI. First, using in-vehicle technology (multimodal sensors, etc.), the user and the automobile can share information in ways other than only on the screen, making the information more varied and three-dimensional. Second, the vehicle system is no longer "hindsight" in RPI-based intelligent vehicle interiors. This means that the user no longer needs to send information to the vehicle system. Instead, the vehicle system will actively sense the user and provide feedback, making the feedback similar to the user's previous experiences, making communication between the user and the vehicle system more efficient and natural. It improves the efficiency and naturalness of communication between the user and the vehicle system. Through the use of physical and psychological sensing technologies, intelligent cockpits can process data directly and offer feedback. As a result of the cross-fertilization of many forms of interaction, current research reveals that RPI may be a new type of HVI. The study of user cognition in the smart cockpit has drawn designers' attention. Future study in the area of HVI may take new avenues suggested by the structural diagram of RPI and the link between the Center of Gravity and the Intelligent Interior.

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