Creating Appropriate Trust in Automated Valet Parking System

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Abstract. To improve the user experience of autonomous driving, human factors issues regarding automated driving need to be addressed. One of the key issues is how much drivers trust in automated driving systems and how they generate trust and reliance based on their experience. This paper aims to investigate how an appropriate level of user trust for automated valet parking system can be created via human-machine interaction (HMI). For example, trust formation is a dynamic process. When users interact with the system, the factors that affect trust will change with the change of context. In order to understand how factors related to trust interact, we designed two projects by modulating four design variables, which are the ease of use, anthropomorphism, transparency of feedback, and communication style. We measure their trust level and satisfaction and provide some design suggestions for creating appropriate trust in the automated valet parking system.

1. Introduction

Trust is the crucial factor in interpersonal domain, and it measures the degree of confidence individuals have in strangers. Yet the significance of trust is not limited to the interpersonal domain, trust can also define the way people interact with technology. In particular, the concept of trust in automation has been the focus of substantial research over the past several decades. In the literature on automation in general, trust has been identified as important for creating willingness to use a system [1] and for ensuring correct use of a system [2, 3].

With the development of autonomous driving and related technologies, trust is regarded as one of the leading human-machine interaction (HMI) issues. Importantly, we should design appropriate trust, not greater trust [2]. Because accidents can occur when operators misuse automation by overtrusting it, or disuse automation as a result of undertrusting it [4]. For instance, the crash of Turkish Airlines Flight 1951 was partially caused by the pilots’ continued reliance on the plane’s automatic pilot after an altitude-measuring instrument failed [5]. Consequently, when interacting with the autonomous driving system, the appropriate trust generated by the user is the key to improving driving safety and establishing good driving experience.

To better understand the factors that affect trust, researchers have studied the trust formation process using a variety of automated systems in diverse experiments. Lee and See (2004) provide an integrated...
review of early research in this area to elucidate the role of trust, and the feelings associated with it, in guiding human behavior toward automation. They consider trust from the organizational, sociological, interpersonal, psychological, and neurological perspectives. Their thought-provoking paper triggered numerous studies on specific factors related to trust in automation that have greatly expanded knowledge regarding the variability of trust. Lee and See do make some design recommendations, but they are relatively loose and cannot be used well in specific system designs.

Hoff and Bashir [1] systemically review recent empirical research on factors that influence trust in automation to present a three-layered trust model that synthesizes existing knowledge. They focused on creating a trust model through an extensive literature study on non-AD systems, e.g., collision warning, route planning, fault management, target identification. They proposed design recommendations for creating trustworthy automation and identified five major design features that must be carefully considered: appearance, ease of use, communication style, transparency, and level of control.

In an online survey of more than 1400 people, Fogg, Marshall, Laraki, et al. (2001) found that for Web sites, credibility depends heavily on “real-world feel,” which is defined by factors such as speed of response, listing a physical address [6]. Similarly, a formal photograph of the author enhanced trustworthiness of a research article, whereas an informal photograph decreased trust [7]. Visual design factors of the interface, such as cool colors and a balanced layout, can also induce trust [8].

However, most literature focus on analyzing the factors affecting trust from the perspective of automation, and these factors cannot be well applied to automated valet parking system design. Automated valet parking is a high-frequency scenario in the future of autonomous driving, and its interactive media include HMI and smartphone application. In this paper, we focus on how to create an appropriate trust for the automated valet parking system and enable users to maintain trust in this dynamic interaction. According to the usability test, we will expand more detailed design factors affecting trust and propose design recommendations. Furthermore, this paper attempts to fill in some of the gaps regarding how to create an appropriate level of trust for the automated valet parking systems via an HMI and app design, identifying trust-affecting factors related to the context of autonomous driving environment and placing them into automated valet parking scenario.

2. Method

![Figure 1. Storyline of Automated valet parking system](image)

2.1. Automated valet parking system design: Two projects

As shown in Fig. 1, in this automated valet parking scenario, the main interaction process of the system is as follows: Firstly, the user can remote control his vehicle on the smartphone, and then the vehicle leaves the parking space and automatically drives to the user's location. After picking the user up, the vehicle drives to the destination selected by the user. At the same time, the user can choose a parking space near the destination on the HMI. When the vehicle arrives at the destination and drop the user off, the vehicle automatically drives to the garage and starts to parking. Finally, the user will receive a driving report when parking completed.

To explore more factors affecting trust, we created four variants to design two projects.

Variant 1 – “Ease of use”. Numerous e-commerce studies have shown a positive relationship between the ease of use of a website and consumer trust [9], and the trust level will increase as the usability of the system improved [10]. Therefore, we adjust the number of user interactions to design two different
processes. As shown in Fig. 2, when the user selects the pick-up point on the smartphone, one way is that the default preference of the system is the user's current location, and the user just clicks the “confirmation” button to perform the remote calling service. The other way requires the user to input the address in the search bar or select the pick-up point in the list. After selection, there is a detailed confirmation page before summoning the vehicle.

Project A

Project B

Figure 2. Remote control vehicle to pick up interfaces
Variant 2 – “Anthropomorphism”. Some research suggests that the anthropomorphism of an interface can be a significant variable [11, 12]. For example, during the interaction process, users may feel confused when they first use the takeover function, so we added some anthropomorphic elements and interesting animations to guide users in the project A. Furthermore, considering the expected age, gender, culture, and characteristics of potential users, HMI will appear the user's cartoon avatar when the user gets into the car and greet the user kindly (see project A in Fig. 3). After the trip, the services experienced by users will be displayed in the form of comics. However, Project B emphasis on presenting information through text and realistic photos (see project B in Fig. 3)

![Project A](image)

**Project A**

![Project B](image)

**Project B**

*Figure 3. Welcome interfaces*
Variant 3 – “Transparency of feedback”. Numerous studies have shown that designing systems that provide users with accurate feedback about their reliability or how they operate can better facilitate appropriate trust [13]. So, this variant is designed to explore the impact of offering users more or less information on trust. Accordingly, project B provided an abundance of information, making every step of the parking process transparent. For example, in the pick-up phase, interfaces will show the location of the vehicle, and provide the vehicle’s movement on the map. As the vehicle drives out of the parking garage, the interface displays the parking time and cost of parking (see project B in Fig. 4). After picking the user up, he can select the parking space near the destination, and the HMI displays detailed information such as price per hour, the opening hours, the number of parking spaces and so on. However, project A provides appropriate feedback throughout the process, it retains the most noteworthy information of the current scene, weakens secondary notifications, and ensures a continuous interaction (see project A in Fig. 4).

![Payment interfaces](image)

**Figure 4.** Payment interfaces

Variant 4 – “Communication style”. Parasuraman and Miller (2004) found that instilling automation with good etiquette, operationally defined as “a communication style that was ‘non-interruptive’ and ‘patient,’” led to greater trust. Therefore, we added voice prompts in the first project. When switching to a driving mode or arriving at a destination, the system will prompt the user with polite voices. Accordingly, we use slightly straightforward words in project B, and such information are presented by text.
2.2. Experimental design

![Figure 5. Experimental test process description](image)

2.2.1. Participants. Eight subjects participated in the study, of which four were female, all were in their twenties. All of them have more than one-year driving experience, and they were not experts in the automotive field and interaction design.

2.2.2. Procedure. The overall experimental testing process is shown in Fig. 5. Before the test, participants were shown the concept video of automated valet parking to understand the nature of the task. They were especially cautioned to describe their ‘first impressions, the immediate feelings’ about the interfaces. Next, participants performed the systems to complete specific tasks. At the end of the experiments, subjects were interviewed in the conference room, and asked for feedback and rated each function regarding the experiment in general and in particular. Interfaces will be displayed on the desk to help them recall their feelings during the operation.

2.2.3. Evaluation indicators and scoring standards. In the survey, we asked participants to rate their trust in automated valet parking systems on 5-point Likert scale items measuring reliance and trustworthiness in systems. We also asked, on 5-point Likert scales, about ease of use, transparency of feedback, communication style about these systems, aesthetics of interfaces. These factors focus on investigating user satisfaction with different design features of the system and examining the relationship between trust. Detailed evaluation indicators and scoring standards are shown in Table 1.

| Trust  | Easy to use | Aesthetics | Transparency/ feedback | Communication style |
|--------|-------------|------------|------------------------|---------------------|
| 1-5    | 1-5         | 1-5        | 1-5                    | 1-5                 |

Table 1. Evaluation indicators and scoring standards
3. Results and discussion

3.1. Results
Results related to the experiment and questionnaires are presented. The effect of design features on the participants' perceptions of: the systems' aesthetics, trust, ease of use, transparency of feedback, communication style was examined.

![Figure 6. Average Trust level in Project A and B](image1)

![Figure 7. Satisfaction score of each design features](image2)

3.1.1. Trust. Overall, as shown in Fig. 6, project A had a higher trust rating with an average of 4 points, while the trust level of project B was 3 points. Surprisingly, the results indicated that with the user's
learning and operation of the system, the trust level of them showed a gradual trend and maintained a relatively high trust level in the middle and late stage of the test.

It revealed that once users begin interacting with a system, its performance can impact dynamic trust, which can change drastically over the course of an interaction. For instance, the differences between initial trust level in projects were not large, but when users operated systems with different design features, the gap between trust was gradually obvious. Therefore, the design of automation is very important, can also impact system performance by altering perceptions of system trust. Furthermore, the change of context had led to different demands for trust from users. For example, when a user summoned a vehicle by remote control, he sat in the vehicle and implicitly need more trust in the next scenario of autonomous driving than the previous scenario. We can see project A had a good effect on trust, and it also proved that aesthetics, transparency of feedback, and communication style had a positive impact on trust. Therefore, it is crucial to evaluate the trust that user needs in different situations.

3.1.2. Design features. Overall, it was apparent from Fig. 7 that project A had a better performance in satisfaction ratings than project B. Among them, there was a significant difference in the indicators of transparency of feedback and communication style. Interestingly, although project B had higher transparency of feedback compared to project A, the satisfaction and trust ratings of project A performed better. Most of those surveyed indicated that an abundance of feedback could be offensive. As a result, it is necessary to provide feedback about particular aspects and adapt to different scenarios. Another important finding was that users felt warm and professional, because of politeness words and voice interaction in project A, which indirectly influence trust.

The aesthetic level of the system affected the user's confidence, and aesthetic design makes people felt that the system was reliable. However, we found that people’s aesthetic standards vary from person to person. Although anthropomorphism of interfaces cannot directly affect the user's satisfaction of aesthetics, soft colors and the reasonable layout are the basis of constructing aesthetic design. Besides, no significant differences were found between the two levels of ease to use. It is possible to hypothesize that ease of use has no significant impact on trust.

3.2. Design Recommendations
Except to evaluate and analyse factors affecting trust, we also provide specific design recommendations based on the interviews.

1. The controllability of system. Trust in automation also depends on the level of control the operator has over automated functions [12]. For example, one interviewee said: ‘When I’m using the automated valet parking system, controllability is vital to me’. As shown in Fig. 8, we have added the manual driving to the autonomous driving process. The pops up indicating the corresponding function makes the originally complicated process easy to understand, making users feel that the system is controllable and reliable, which improves the trust level of the system.

![Figure 8. Engage AutoDrive and take over requests](image-url)
2. Evaluate users’ trust requirements in different scenarios. When using the automated valet parking system, users usually interact with the system in different scenarios, such as remotely controlling the vehicle in the office or outdoors, enjoying autonomous driving on the vehicle, and then dropped off before the vehicle automatically parking. In different situations, users need different senses of security and trust level, so the variables that affect trust should be designed separately. Therefore, designers need to understand the specific demands of users in the current situation and provide corresponding feedback.

3. Visual communication. There are many ways to convey information visually. Although anthropomorphism of an interface can be a significant variable, designers must consider the expected characteristics of potential users (e.g., age, gender, culture), as anthropomorphizing an interface can impact the trust formation process differently for diverse individuals [14]. We find that it is important to choose the appropriate communication method based on the current scene. As shown on the left side of Fig. 9, most users want to see the real-time video during autonomous driving, because it is closely related to the security of the vehicle. However, to create the initial trust, we use anthropomorphic illustrations to guide users on which services they will experience so that users can quickly understand the context (see the right side of Fig. 9). Therefore, the use of anthropomorphism requires serious consideration in the system.

![Figure 9 Real-time video and service introduction interface](image)
4. Emotional design. Trust may depend on a wide range of cues and that the affective basis of trust can be quite sensitive to subtle elements of human-automation interactions. Promoting appropriate trust in automation may depend on presenting information about the automation in a manner compatible with the analytic, analogical, and affective processes that influence trust [2]. Therefore, designers should apply emotional design to touchpoints. For example, at the end of the experience, the driving report presented by the smartphone can be warm and sweet. As shown in Fig. 10, ‘In the autonomous driving
journey, you can avoid walking under the sun for being 16 minutes, pre-reserved parking slot saves you 17 minutes and so on’. This scenario-based narrative method can easily resonate with users, improve the system’s favourability, and lay the affective basis of trust.

4. Conclusion

The results of this study may be used as a base for wider research about the automated valet parking system design, and we explored the impact of ease to use, aesthetics, transparency of feedback, and communication style on trust. As reviewed in section 3.1, we found that the aesthetics, transparency of feedback, and communication style had a positive impact on trust, but the highest transparency of feedback will not get a higher level of trust. Therefore, we should consider these design variables matching different scenarios. Furthermore, the results of this study indicate that the limited impact of ease of use in automated systems on trust. At the end of this paper, we refined some design suggestions from interviews, including adjust the controllability of the system and evaluate user trust needs in different scenarios. From a design point of view, designers should choose the appropriate communication method based on the current scene and apply emotional design to the system. These design features and recommendations can be well combined with dynamic interactions to create an appropriate trust for automated systems and help designers to complete complex tasks of the system.

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