Master's Thesis of Design

Time and Location Base UI Automotive Cluster Design in Perspective of 'Passenger'

'탑승자'의 관점의 시간, 위치 기반 차량 클러스터 UI 디자인 프레임 제안 연구

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Time and Location Base UI Automotive Cluster Design reflecting Personal Situation of 'Passenger’

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Abstract

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One important design issue is the examination of how the user interface (UI) supports the new user role in future mobility. However, there are few design studies on the passenger's cognitive needs and behavior in Autonomous Vehicles (AVs) based on empirical data. There is no doubt that autonomous mobility technologies are growing. The technology is already aiding the driving experience, and it will change the mobility culture and the transition of 'driver' into 'passenger.' This study is based on the premise that future AV is capable of performing all driving tasks. It proposes a set of passenger-centered automotive cluster UI designs for future mobility employing two factors: time and path. A set of empirical data is provided to understand the passenger's perspective.

In this study, a solid set of empirical data on the cognitive needs of passengers is collected. Human cognitive characteristics and driving tasks are investigated from various viewpoints to understand the passenger's perspective. The cognitive relationship in the driving environment is analyzed through a literature review on situation awareness (SA) and structuring of the data flow framework. The framework is further explored by connecting the technological role transformation to the passenger. To construct the empirical database on the passenger, three sets of user tests and in-depth interviews were undertaken. The user tests were designed employing the Wizard of Oz method, and the results were summarized using descriptive and exploratory analysis. Based on these insights, a set of UI designs from the perspective of the passenger was proposed, and usability tests were conducted to verify its effectiveness and usability.

The results of the tests demonstrate that a major percentage of the information request was related to time (current time and duration) and path (vehicle location and surroundings). Based on the data, a UI framework was built. Two usage scenarios were designed, time-full and time-less, for better in-situation comprehension. Time- and path-based UI were proposed to flow with the scenarios. A usability test was conducted, and a passenger's cognitive framework was defined. There are two aspects to this study: the data flow frameworks of the driver/passenger, and the UI design proposal. Situational precision from the perspective of the driver was analyzed to understand the relationship between the user, the vehicle and the road conditions. Further, the cognitive framework of the passenger was proposed based on the data.

This study provides a solid understanding of drivers' emerging needs when they are relieved of the cognitive burden of driving tasks. The UI features for AV are introduced based on the empirical data and research related to the provision of better situation awareness, focusing on time and location. This study contributes to the extant literature by observing the perspective of passengers in Autonomous vehicles based on a qualitative study. The proposed UI design will be further explored as a communication method between the system and the passive user in future mobility.

Keyword: AV passenger; passenger-centered cluster UI; data flow frameworks; autonomous vehicle; situation awareness;
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Chapter 1. Introduction

1.1. Background

Automated vehicles (AVs) are expected to disruptively transform mobility culture as they change the operator in a vehicle[①]. Google's complete Autonomous vehicle, Waymo, and BOSCH's automated valet parking system are paramount examples, demonstrating that mobility forms change as the vehicle connects one space to another without the stress of driving. There has been much debate between those who approve of AV technology in terms of safety and reliability. Opponents have long argued that the ethical dilemmas and the financial burden of rebuilding social infrastructure remain[②]. However, the benefit that AV will bring to society may well be huge: it provides liberty from driving stress and expands mobility choice for vulnerable users[③].

Automation already takes part in various kind of transportation. The autonomous subway is already in its service since 2017, and the semi-autonomous

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① Alessandrini, A., Campagna, A., Site, P. D., Filippi, F., & Persia, L. (2015). Automated Vehicles and the Rethinking of Mobility and Cities. *Transportation Research Procedia,5*, 145-160. doi:10.1016/j.trpro.2015.01.002

② Clark, B., Parkhurst, G. and Ricci, M. (2016) Understanding the Socioeconomic Adoption Scenarios for Autonomous Vehicles: A Literature Review. Project Report. University of the West of England, Bristol. Available from: http://eprints.uwe.ac.uk/29134

③ Bagloee, S. A., Tavana, M., Asadi, M., & Oliver, T. (2016, August 29). Autonomous vehicles: Challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation,24*(4), 284-303. doi:10.1007/s40534-016-0117-3 cars with the 'pilot mode' such as the Tesla Model S are already on the road [④]. The autonomous technology is currently utilized at a limited level, but there is no doubt that autonomous mobility technologies are growing.

It will also dramatically improve mobility safety by reducing stress caused by cognitive burden[⑤]. In manual driving, a driver is required to engage with multiple information sources, mechanical manipulation, and strategy implementation[⑥]. In contrast, an AV system diminishes cognitive burden by reducing stress arising from concentrating, multi-functioning, and information processing. It has the potential for at least a 40% fatal crash-rate reduction due to human failings and current regulatory loopholes[⑦].

The technologies support drivers with a reliable resource, and the effect of the technology is already observant on the current road. For example, most of the recently released car models contain rearview sensor system which provides video footage through a screen and collision avoidance safety feature, which gives a warning sound when there is an obstacle close to the car. Some vehicles carry cruise control that the system automatically controls the car in the lane while driving. Drivers now look into the screen on reverse gear when they used to look

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④ Hsu, J. (2016, March 07). 75% of U.S. Drivers Fear Self-Driving Cars, But It's an Easy Fear to Get Over. Retrieved August 6, 2018, from https://spectrum.ieee.org/

⑤ Bagloee, S. A., Tavana, M., Asadi, M., & Oliver, T. (2016, August 29). Autonomous vehicles: Challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation,24*(4), 284-303. doi:10.1007/s40534-016-0117-3

⑥ Lee. J. S. "Human Factors in Driver's Speed Control and Information Processing: Effect of Driver's Eye-Level and Cognitive Load." Korea Journal of Experimental and Cognitive Psychology, 8.2 (1996): 345-366. Print.

⑦ Endsley, M. R. (1999). Level of automation effects on performance, situation awareness and workload in a dynamic control task. *Ergonomics,42*(3), 462-492. doi:10.1080/001401399185595 into the side mirror, drivers listen to the warning sound of wall detection when they used to guess the distance to the wall with feeling, and driver lightly place their hands on the steering wheels on the highway with the cruise control when they used to hold on to it tight. The new technology changed the deliverance of data that the driver requires, and it affects the driver's behavior. So, its effects will grow more heavily as it processes more tasks in driving.

The behavior of the driver in AV becomes more like that of an 'AV passenger,' and the role and associated tasks are affected by technology[⑧]. There are revealing design concepts demonstrating the transition of the driver's seat into a passenger's seat in future mobility experience[⑨]. Unlike a driver's tasks in manual driving, the 'AV passenger' is focused on communication with system status rather than vehicle manipulation. Endsley (1999) revealed that the operator (the 'passenger') concentrates more on monitoring and judgment for intervention as the automation level becomes more advanced[⑩].

The autonomous system is a mutual connection between platforms, which means it connects the user between different system, and it highlights the system-user communication method. When the automation level is mature enough to handle all the driving tasks, the vehicle's function becomes a connecting space between one space to another. Instead of manipulation on the vehicle, the user

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⑧ Ohn-Bar, E., & Trivedi, M. M. (2016, March). Looking at Humans in the Age of Self-Driving and Highly Automated Vehicles. *IEEE Transactions on Intelligent Vehicles,1*(1), 90-104. doi:10.1109/tiv.2016.2571067

⑨ Cuddihy, M. A., & Rao, M. K. (2015). *U.S. Patent No. US 9,199,553 B2*. Washington, DC: U.S. Patent and Trademark Office.

⑩ Endsley, M. R. (1999). Level of automation effects on performance, situation awareness and workload in a dynamic control task. *Ergonomics,42*(3), 462-492. doi:10.1080/001401399185595 communicates with the system in order to move between location. For example, Automated Valet Parking System (AVP) is an unmanned parking system designed by BOSCH in the Mercedes-Benz Museum in 2018[⑪]. The project proposes a parking system that the autonomous car finds an open parking space and park itself when the driver drops off their car anywhere near the parking space. When the driver needs the car, the user calls the car to their location through a smartphone app, as described in Figure 1.

Figure 1. Automated Valet Parking (AVP) system usage map. (Source: BOSCH Global official website)

AVP is an example of a collective connection between different platforms. In AVs, when the AV system manages all the driving tasks, the user reflects their needs or gain information through communicating with the system. One of the methods is the smartphone APP, as shown in AVP by Bosch. Driving always

⑪ Bosch Global. "Automated Valet Parking – Don't Get Stressed, Get Parked." *Bosch Global*, 19 Dec. 2018, www.bosch.com/stories/.

comprises with parking. If the user's journey between departure to destination laid out as a series of spaces, it would be departure place-parking lot-vehicle-parking lot-destination. Massive amount of cognitive and physical energy is wasted for looking for a parking space and getting out the vehicle. Drivers spend their times and gas for wondering around the parking lot looking for an open space, and when parking cost enough stress as well. According to the BOSCH's main slogan for AVP, "No more Maneuvering and no more gymnastics when getting out of your car," the autonomous technology reduces the wasted time and energy and to solely focus on mobile time only. In that process, the user urged to communicate with a parking platform; it means the complete autonomous driving is a mutual connection between different platforms for different functions. The user needs to be involved with at least three different platforms: parking-out, autonomous driving, and parking-in. It highlights the coherence of the UI for future mobility. The UI needs to provide enough but yet not complicated information for the user in order to connect between different spaces.

Figure 2. Future Road traffic flow presented by Wanis Kabbaj. (source: TED Science & Technology, 2016)

The autonomous system affects not only on the inside of the vehicle but every driving system. The future road map presented by Wanis Kabbaj in TED talk 2016 flows like a blood vessel, as shown in Figure 2. The aggregate traffic information includes each vehicle's driving route, and the next movement is all connected and communicated. The traffic is pre-calculated and adjusting themselves to avoid interfering with each other. Hence, the speed of the vehicle will move like a regulated flow without tailgating or traffic jam. Therefore, the future road map is without any visible traffic system such as traffic lights, regulation signs, or road signs[12].

As the future road map drastically changed, the user interface for the future mobility needs changes. Following the previous study of BOSCH and Wanis Kabbaj, many of the driver's task will be taken by the AV system, and the driver

[12] Kabbaj, Wanis. "What a Driverless World Could Look Like." *Ted*, Ted, www.ted.com/talks/.

would act more like a passenger. However, there is a clear difference between the passenger in the driver-existing car and AVs. Their approach to the driving situation and the type of information that they seek would be distinctive as well. In manual driving, it was important to provide all information to the driver in order for the driver to make an informed decision. A good cluster UI design in the manual driving situation was designing an efficient and high fidelity visualization. As of AV technology, AV system manages driving tasks with the high technology sensors, data processing, and GPS technology. The transition affects the driving environment and needed context for the in-vehicle UI. Therefore, the informational context for future mobility needs to be reconsidered and re-examined in the perspective of a passenger.

1.2. Purpose

This study aims to provide an empirical understanding of 'Passenger's cognitive needs and propose a passenger-centered User Interface in Autonomous. The procedure is based upon the premise that the automation technology is fully operative and trusted.

For the reconstruction, it is an important outline to define the cognitive model of the driver in a manual driving situation and the passenger in AVs in order to define a set of required information for future mobility. In the manual driving situation, the driver needs to handle multiple tasks: reviewing road situation, predicting the possible threats, reading the vehicle's mechanical information and controlling the vehicle according to the surroundings. The competitive judgment is required, and it is easy to exceed the human cognitive limit and leads to an immature judgment. On the other hand, the cognitive burden in AVs is reduced. The system is eligible to maintain the mechanical state such as speed and gear change, breaks, and direction control. The technology unloads the cognitive burden by acquiring the driver's task.

With autonomous, it broadens the view of a vehicle from the physical space to the intangible mobility. As the system replaces the driver’s task, the ‘driver’ changes into ‘passenger.’ It is not the simple role change, but it is the change of driving culture, which effects on the formation of space, information and experience of mobility. The broader the system’s capacity, the greater the need for system-human communication through visual feedback of system activity and interventions. It is important to define the culture of the passenger to redesign the user interface within the AVs.

1.3. Research Question

Cognitive elements elevate situation awareness. As a result, identifying the most desired informational elements is an important matter when designing UI[13]. The fundamental understanding of cognitive needs from the perspective of the passenger, rather than the driver, is an important research approach for future mobility development.

[13] Endsley, M. R. (1999). Situation awareness in aviation systems. In D. J. Garland, J. A. Wise, & V. D. Hopkin (Eds.), Human factors in transportation. Handbook of aviation human factors (pp. 257–276). Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.

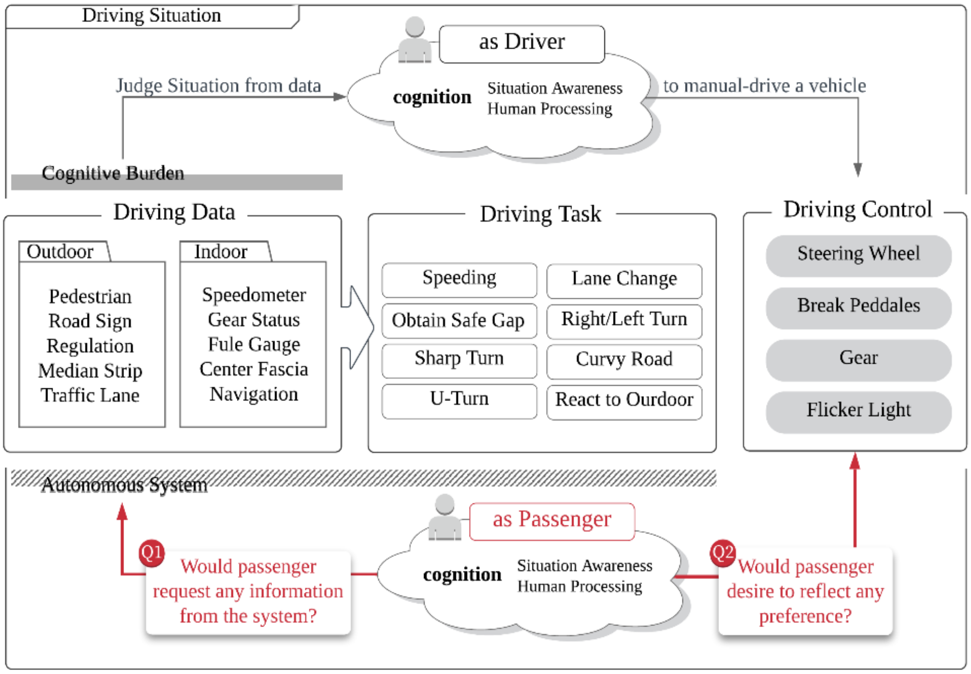

Figure 3. Data flow framework in driving situation in perspective of Driver and Passenger.

Based on extant studies of the relationship between information, the driver and vehicle control[14], the data flow between the data source, the user (driver) and the car is illustrated in Figure 3. In a manually operated vehicle, it is represented by one-way interaction as demonstrated on the upper side of Figure 3. The user is the 'driver,' who perceives both outdoor and indoor driving data and performs 'driving task' based on personal judgement. The driver's task is done through driving control, which states mechanical manipulation of steering wheel, break paddles, gear, and flicker lights. The driver is the sole subject with decision-making capabilities.

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[14] Choi J.W.,Park H.S.,Kim K. H., "The Modal Selection for Human Vehicle Interface to Provide Information with Drivers", Ergonomics Society of Korea Conference Proceedings/ 2010(5), 2010., 254–257, Ergonomics Society of Korea

As for the AV, the data flow changes, as shown in bottom side of Figure 3. The intervention of the driver is unnecessary. Based on the premise that the car (the system) is capable of all driving tasks, especially starting from level 4 automation, where the system is capable of executing all driving tasks and decision making, the system becomes the center of the main data flow. The 'driver' becomes the 'passenger,' who carries cognitive abilities and needs relevant to situational understanding. In that circumstances, two research questions arise: would the passenger request any information from the system and would the passenger desire to reflect any preference?

In Endsley's research (1999), the human operator showed a willingness to review the system's activity and to be involved in the system's decision-making process. Adapting this study to a driving situation, the monitor that displays the system's activity corresponds to the cluster UI. Extant studies have analyzed the user's perspective in driving situations. Lee (1996) examined the relationship between a driving situation and driving behavior. Choi et al. (2010) analyzed the overall task in a given driving situation and suggested the most suitable cognitive direction for each task. However, few studies have collected empirical data from a passenger's perspective, especially in a personal vehicle driving situation. The driver's cognitive state and the tasks have been identified in detail as they are directly related to safety, but the passenger's state of mind is not critically considered. AV will dramatically change the mobility culture. Understanding the passenger's perspective helps to lay the foundation needed to accept the new mobility.

The current cluster UI is designed from the perspective of the driver: the data that the driver needs to review while driving, as well as the mechanical data they need to control. Then, when they are exempted from the burden, the cluster UI in AV needs to be decontextualized from the perspective of the passenger. Whereas the driver's cognitive capability was primarily used for advancing tasks as described in Figure 3, the passenger's cognition expands to review overall system activity and to assist in improved searches.

Understanding the context and the situation in AV is the fundamental goal of this study. Therefore, the passenger's requested information and reflection of preferences in the system are the two research questions addressed in Figure 3.

Chapter 2. Literature Review

2.1. Sitation Awareness (SA)

Cognitive elements elevate situation awareness. As a result, identifying the most desired informational elements is an important matter when designing UI[15]. The fundamental understanding of cognitive needs from the perspective of the passenger, rather than the driver, is an important research approach for future mobility development.

Context awareness is a system method that understand the user's situation in advance and provide information that the user desires[16]. Context awareness

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[15] Endsley, M. R. (1988). Design and Evaluation for Situation Awareness Enhancement. *Proceedings of the Human Factors Society Annual Meeting*, *32*(2), 97–101. https://doi.org/10.1177/154193128803200221

[16] Soegaard, Mads, et al. *Encyclopedia of Human-Computer Interaction*. 2nd ed., Interaction Design Foundation, 2013.

originated from the term ubiquitous computing, or pervasive computing, for link changes in computer system. It is mostly studies as property of a mobile device along with the location awareness. Location Awareness determines how much the device has pinpointed location. While Context is about how users get more flexible access to mobile users. The concept is also applied to business theory in relation to application design and business process management issues.

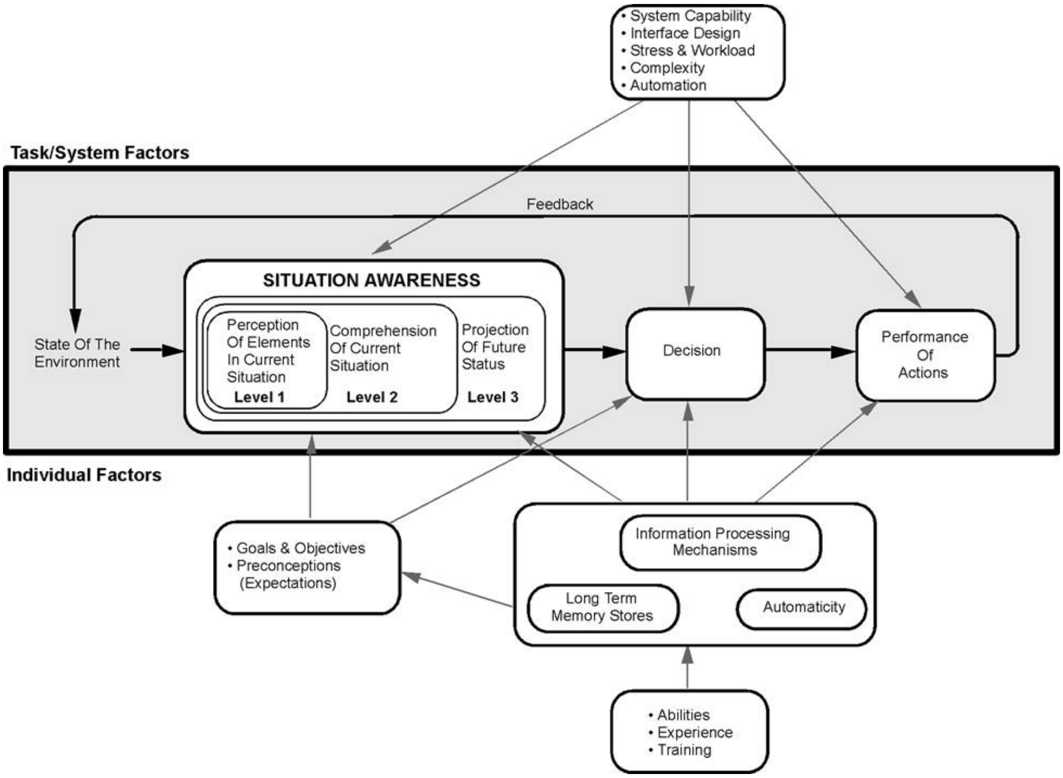

Figure 4. Endsley's Theoretical Model of Situation Awareness in dynamic decision making (1995). This explains how the decision make happens in a variety of domain.

Situation Awareness (SA) is addresses the relationship of design features, workload, stress, system complexity and automation of a device or a system[17]. The

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[17] Endsley, Mica R. "Toward a Theory of Situation Awareness in Dynamic Systems." *Human Factors: The Journal of the Human Factors and Ergonomics Society*37 (n.d.): 32–64(33). In Print.

model in Figure 4 is an illustration of which domain the SA takes in the dynamic decision-making process. Situation Awareness is developed to increase the flight safety and operational utilization in aircraft. Endsley found there is a high consequence with the design feature and the pilot(user)'s situation reading. The SA model contributes to understand the consequence of user's behavior by analyzing the sequence of situation reading from the environment to the performance.

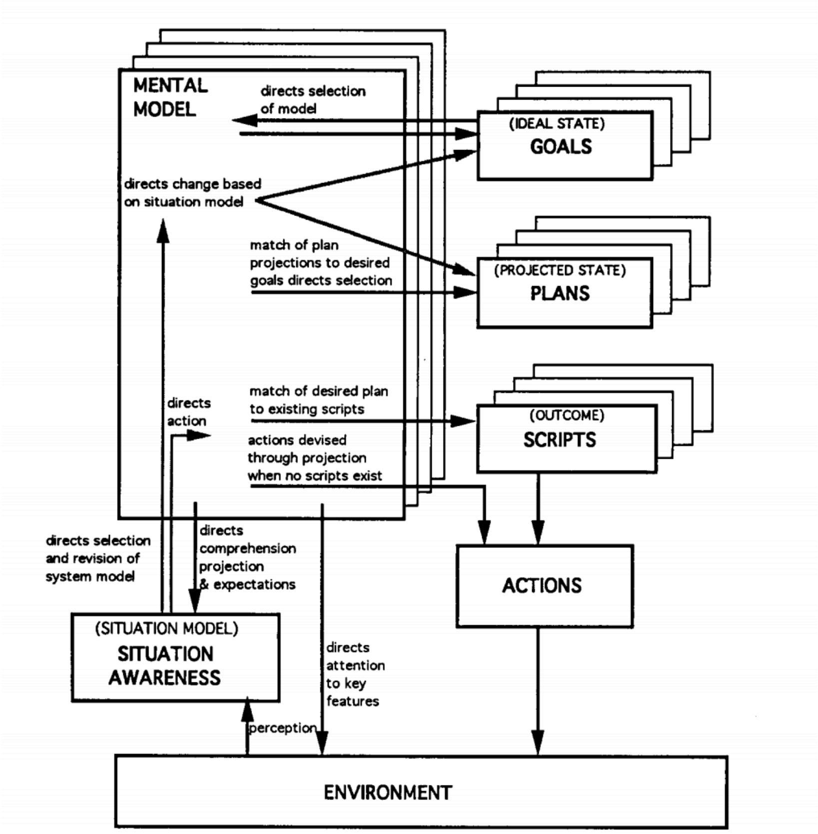

Figure 5. Endsley's model of Relationship of goals and mental models to situation awareness (1995).

Endsley had a goal-oriented view point on the SA. She claimed that the SA happens to achieve a specific goal or desire. As described in Figure 5, the base information provider and projector is the environment. The user adopts information from information and processes SA. Through SA, the user moves to the Mental model and it intercommunicate with goal-oriented process. First, the user set the goal of the outcome, and the plans to procedure, and then the scripts of plan. As a result, the user result on the action in the environment. This set of mental models is based upon the SA and the adaptation and the resulted action varies on the SA.

As SA is applied in the design field, it is the concept that a device provides the appropriate information to 'fit' to the user's pattern without any active action by the user. Gartner mentioned the emergence of the Context Rich System which is a system that understands the user's environment with a clear understanding of the user's needs in the top ten technology strategies in 2015[18]. Context in designing process is the user's story, which means context-awareness designing is providing a live story with the product for the user.

Contextual product is every story related to user experience that help to fulfill their needs with the minimal interaction. Context allows the user to feel like the product understands the user completely. To design a contextual product, approach to in two different perspective is the first step. One is being smart and second is getting familiar to the interface in consideration of interaction. To understand the user's context, three elements are required: user story, standard interface and contextual interface. Contextual Product minimize the standard interface and provide dramatically simpler or considerate interface. It gives the feeling of answering the user's questions before asking. Context-awareness helps to understand the user's perspective more effectively with the understand of existing usage process by expanding thoughts in a specific situation.

[18] Gartner, Inc. (2014, October 8). Gartner Identifies the Top 10 Strategic Technology Trends for 2015. Retrieved from www.gartner.com.

2.2. Human Information Processing Model

Human Information Processing Model, also known as Model Human Processor (MHP) is proposed by Card, S.K., and Moran T.P., & Newell, A in 1983[19]. This theory explains how human adopt and store extraneous information, and how they recall the stored information with a specific trigger[20]. Card et al. sees the human memory system as an active process of information processing such as encoding, storing, and retrieving information. According to the theory, there are four primary rules: 1. Information is processed step by step. 2. Learning is a progressive process. 3. The information processing system is interactive. 4. Learning is environmental stimulation and interaction with the learner.

As described in Figure 6, memory consists of three separate slots of memory storage: sensory memory, short-term memory, and long-term memory. Sensory memory is a temporary memory that is received from the situation. It has a short duration of about 2 seconds with unlimited capacity. Short-term memory also called Working Memory, is the combination of the knowledge of long-term memory with the temporary memory of the new information. Cognitive processing of information occurs for this step, and its capacity is limited. In order to overcome the capacity limitation, it is possible to store the memory in the long-term through encoding such as chunking, which is connecting process with memory to a stimulus

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[19] Jae Yong, Lee. "What Is Model Human Processor (MHP)?" *Pxd UX Lab.*, TISTORY, 6 July 2014, www.story.pxd.co.kr.

[20] Card, Stuart K., et al. *The Psychology of Human-Computer Interaction*. Lawrence Erlbaum Associates, Inc., 1983.

or specific meaning. Long-term memory is a permanent informational repository, and its capacity is unlimited and perpetual. There are three types of memory: an episodic memory which is a personal experience, a semantic memory which includes problem-solving strategies, logic, facts, concepts, rules, and common-sense gained from experience, and a procedural memory such as driving.

The information processing begins with attention to stimuli. The learner goes through stages of perception that give meaning and interpretation to experience. Attention concentrates on the stimulus. The experience influences this. After the cognition, a demonstration process happens in working memory. It is an iterative process like reading information aloud or repeating it inward. Encoding follows as associating new information to the existing information in long-term memory. It is the process of moving information from short-term memory to long-term memory. It is the most critical process in the M, and it is necessary to have meaningful coding. The retrieval process, which is the process of finding information in long-term memory, is followed. The success and failure of withdrawal is a factor of mobility and accessibility.

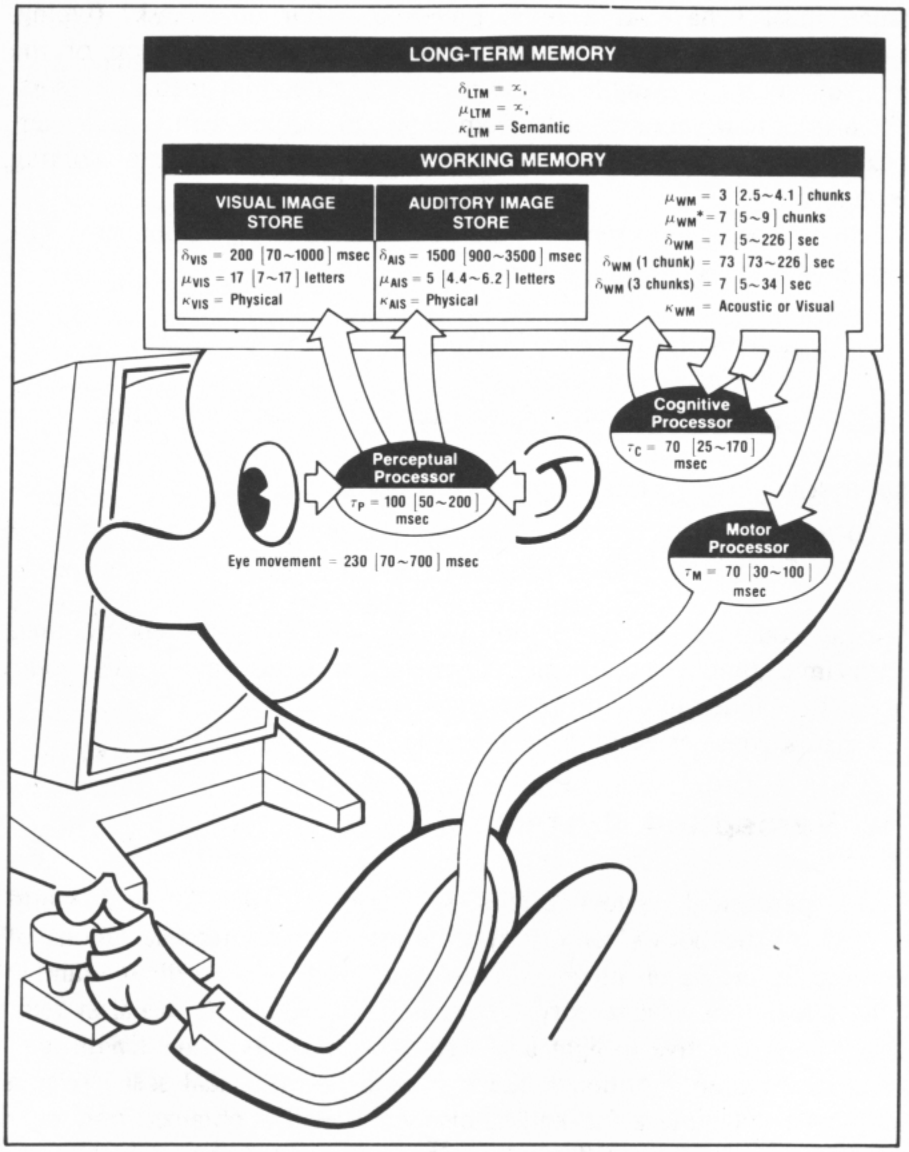

Figure 6. Card et al's model of Human Information Processer (1983). It is an illustration of the cognitive model to calculate the time to process a task in response to a certain stimulus.

Kwon et al. ran a user experience on procedure education using procedural memory in the research " Efficient Interface of Procedural Memory - In case of repeating segmented video" [21] . Experiments were utilizing the concept of

[21] Kwon, I., Kim, G., Nam D., Han, K., Kim, M. "Efficient Interface of media in Procedural memory." HCI Korea, (2014): 1077-1081. Print.

procedural memory, which a type of long-term memory. Her research expresses that developing familiarity through visual exposure to a task situation repetitively enforce the education of procedure task.

In the case of procedural memory, it is efficient to provide a story in motion, such as video, because there are parts that are difficult to explain through picture or text. Especially the tasks that require human motion techniques, such as puzzle ring and knotting, learning through video was more efficient and easier to understand than the pictures.

Experiments were conducted to determine what medium is suitable for procedural memory learning among video, repetitive video clips by steps, and still images. There are two states of the Experiments as Experiment1 and Experiment2. Experiment 1 was conducted to determine the efficiency of procedural memory depend on the testing media. Experiment 2 was conducted as a control experiment to see if the result of Experiment 1 varies on the type of learning material.

The learning content of Experiment 1 was shoelace tying and for Experiment 2 was an educational documentary 'three books' produced by EBS. Both experiments provided in one of three media to the participants: video, repetitive video clips by steps, and still images. The video was set to playback/ pause/rewind for the convenience of the participant, but the speed control was disabled. In the case of repetitive video clips by steps, it used the same video but edited in parts for each step. Participants were able to watch one clip repetitively as desire, and they could move to the next step by pressing the button at any time. However, once they move on to the next step, rewind to the previous step was enabled. The still picture was a capture- image of the same footage. The pictures were presented in a vertical direction on the screen. Participants were able to scroll down to the desired scene. All media were experimented without providing sound for uniformity of conditions.

The results show that there is a significant difference in the efficiency of the learning process according to the media. The number of correct answers was higher in the group that received the video than in the group that received the step - by - step repeated video clips and the group that received the still pictures.

With the study, the examiner on which media is most preferred and efficient for procedural memory learning among the three types of media. It can be seen that, in general, procedural memory learning is preferred for repeatable and easy-to-follow media. Procedural memory learning seems to be the most efficient step-by-step repetitive clip because it requires less time to learn and to follow procedures. In the case of the video, the participant's satisfaction was high, but it took a long time. As a result of the questionnaire on efficiency, the repetitive segment clips were evaluated as the most efficient method.

The research of Kwon et al. shows that appropriate viewing time and moving image of the process is the critical elements for process education. Providing video gives the user the feeling they are provided with enough information to follow, and short running time reduces the stress to focus on the video itself entirely. It is the example of iterative learning that reinforces the cognitive processing, which is deemed necessary in the HMP. Repetitively encode a particular process as a Temporary memory and help cognitive processing to be perceived more efficiently as the long-term memory. The research also emphasizes the importance of choosing the right media for the targeted procedural learning content.

2.3. Driving Situation Awareness and Perspective

The influence of cognition on driving tasks has been studied in various angles. There is a comparative study of the driver 's control behaviors according to the visual perspective level, in the research on the composition of the automotive interface.

Lee J.S. examines the relationship between the driving situation and the actual driving behavior in his research "Human Factors in Driver's Speed Control and Information Processing[22]. Also, the research suggests that visual cognitive load is closely related. The effects of perceptual or cognitive characteristics on driving have been studied extensively, but a few researches have been reported on driver 's speed control or information processing performance when changing driver' s perspective and driver 's cognitive burden is systematically controlled.

A number of variables were used in the experiment. The driver's average driving speed, free recall rate, and subjective elapsed time estimates according to road complexity were analyzed. In Experiment 2, the driver's eye level and cognitive load level were controlled, and the driver's attention was measured in different senses (Auditory vs visual) and task complexity (complex vs simple).

The results of the two experiments: (1) Higher Eye level (6 feet) had faster-driving speed, better free recall, and more and reported an underestimated subjective lapse of time than the lower eye level (4 feet). (2) the complexity of the road is an essential factor in the driver 's speed control behavior, and drivers tend

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[22] Lee. J. S. "Human Factors in Driver's Speed Control and Information Processing: Effect of Driver's Eye-Level and Cognitive Load." Korea Journal of Experimental and Cognitive Psychology, 8.2 (1996): 345-366. Print.

to operate at a slower speed than a simple road. (3) The effect of the eye level was constant according to the level of the various target speeds, and visual and complex tasks had more critical impact on driver's attention that cause slower speed and poor information processing performance than the auditory and simple task had.

Cognitive load is negatively correlated with driving speed and free recall rate. On the other hand, there is a static correlation with the estimation of the personal elapsed time. The research states that the driver 's eye level increases the driving speed and free recall rate, and underestimation tendency of subjective elapsed time affected on cognition. This study states that most of the driving task is processes with visual information. The driving speed is affected by not only the driver's cognitive burden but also by the distractive modality (i.e., visual or auditory). Road cognition difference due to the perceptive level change is mainly related to visual urge. On the other hand, the driver 's speed control or information processing is more related to the visual distraction.

The critical question in the study is why driver's eye-level effect is not significant in hearing-simple condition and visual-complex condition. The results in visual-complex conditions may affect the difficulty of the task that has overwhelmed the driver than the eye level difference.

It is observed that visual and complex attention distractive tasks reduce the driver's speed control or information processing performance more critically compared to auditory or simple attention dispersion tasks. It also provides important implications for human (driver) -environment (road) interaction patterns such as human (driver) -maintenance (automobile) interaction patterns that should be considered in the design of displays in an automobile or the installation of road signs.

In other words, in order to provide the driver with the desired information, the in-car display should be designed to reduce the visual burden by distributing the sensory input. For example, it is better to provide a warning signal of a malfunction as audible. It is because the driver has to move their eyes off of the road to see the warning if the signal is given visually on the dashboard cluster screen. The case of road signs is also important to avoid installing multiple numbers of signboards at specific locations or providing too complicated information within a signboard. Especially in the driving situation, the driver is in a fast-moving vehicle, and the time-constraint in the information processing is large. Therefore, the driver's information processing ability need to be considered.

2.4. Driving Task and Sensory Interaction

Lee's Research addressed in the previous section is confined to the speed control and information processing task. Further, Choi et al. analyzed the overall task in the driving situation and suggested the most suitable cognitive direction for each task[23].

As asserted in the above study, it is a step further from the claim that a balance between multiple sensors should reduce cognitive load. It is basic knowledge to know precisely the necessary functions in the driving situation. It helps to classify the tasks that can be replaced by the system in the future

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[23] Choi J.W.,Park H.S.,Kim K. H., "The Modal Selection for Human Vehicle Interface to Provide Information with Drivers", Ergonomics Society of Korea Conference Proceedings/ 2010(5), 2010., 254-257, Ergonomics Society of Korea

autonomous and to design an effective cognitive delivery system that meets the needs of the passenger.

Choi et al. mainly focus on the suitable modal interface for providing sufficient information to the driver based on the driver's situation, driving load information and the vehicle status information. They propose a selection process of the interface formation that is suitable for driver per modal in consideration of cognitive burden based on the research on the driver's psychological state through the sensor. It is for analyzing the information that is possibly provided to the driver such as the indoor and outdoor environment, the mechanical state, and the distance information with the other vehicle, and its effect on the driver through the given information.

This research analyses the driver's cognitive load for the intelligent interface and analyses the pros and cons of visual, auditory, and tactile information providing method per each driving tasks. The visual interface can expose the input information for the lightest time, but it gives heavy cognitive load to the user. There are three types of representation interface: HUD, TFT, and LED. The auditory interface can be immediately recognized to the user, but it is greatly influenced by the surrounding environment, and the recognition remains short. There are two types of the auditory interface: Speaker and Buzzer. The tactile interface has the advantage of being directly recognizable to users, but it also heavily burdens cognitively similar to the visual interface. The tactile interface can be divided into three parts, haptic steering wheels, haptic seats, and haptic seatbelts.

Choi defines the driving situation as 'TASK', and explain how to provide the visual, audible, tactile modal interfaces according to TASK. Approximately 80-90% of the cognitive information that the driver requires is obtained visually. The driver's vision is affected by the brightness, vehicle speed, the reflectance of the object, and so on. The higher the speed of the car, the shorter distance the driver can see. In general, vision is more dominant than auditory in spatial perception, and hearing is more dominant than visual in temporal perception[24]. Table 1 shows how to provide a priority interface for visual, auditory, and tactile modal tasks according to the task.

Table 1 Driving Tasks categorized by sense (Source: Choi J.W. (2010), "The Modal Selection for Human Vehicle Interface to Provide Information with Drivers")

Visual Interface	**Auditory Interface**	**Tactile Interface**
Signal waiting	Drowsy driving	Drowsy driving
speeding	Sharp turn	Sharp turn
Nighttime driving	U-turn	U-turn
Unobtained safe distance	Phone call while driving	Phone call while driving
	Cut in	Cut in
	Lane change	Lane change
	Lane departure	Lane departure
	Right/left turn	Right/left turn
	Signal waiting	Signal waiting
	Highway driving	Highway driving
	Narrow lane	Narrow lane
	Curve road	Curve road
	Over speed	Over speed
	Unobtained safe distance	Unobtained safe distance
	Obstruction sensing	Obstruction sensing
	Unbuckled Seatbelt	Unbuckled Seatbelt
	Drunk driving	Drunk driving
	Window opening	Window opening
	Electronic device	Electronic device

[24] Shimojo, S., Shams, L., Sensory modalities are not separate modalities: plasticity and interactions, Curr. Opon. Neurobiol., Vol. 11, pp. 505-509, 2001.

As shown in Table 1, in the case of signal waiting, speeding operation, night driving and securing of the safety distance, visual attention is preferential should be provided visually to the driver. Since the driver 's vehicle is stationary, the visual load is low in the spatial sense; it is appropriate to provide such information in the information visual. In the case of the over speeding and the nighttime driving, LCD is preferable because the driver watches the situation ahead. Finally, in case of Unobtained safe distance, the driver should provide the LCD because the driver is watching the situation ahead and the road situation.

TASK that provided with both auditory and tactile shown in table 2, it is because the visual display has a high cognitive burden, so it is proper to provide via auditory and tactile to lower the burden. It shows the classification of appropriate display methods of each sensor according to the risk level. The risk level is divided into High, Middle, and Low, and the information is provided as follows, modally, according to the level in the urgent situation.

Table 2 Classification by severity level by Visual, Auditory, Tactile sense (Source: Choi J.W. (2010), "The Modal Selection for Human Vehicle Interface to Provide Information with Drivers")

Level / Sense	High	Middle	Low
Visual	Emergency light, LCD display with large-sized text warning in red and screen flicker	LCD display with text warning in red and screen flicker	Change to normal display mode, display information on the LCD in normal size
Auditory (output in danger sensed	fast Cycle Beep and Voice Information	Average cycle beep and voice information	Messages in plain tone voice

direction)			
Tactile	Seat vibration, Seatbelt vibration and tightening	Seatbelt vibration and tightening	Seat vibration

The 'High' level of Visual changes the display mode to the emergency, and the additional emergency flashing and the high visibility color on the LCD. The 'middle' level displays the text warning in red and flicks the screen. On 'Low' level, it converted to the normal display mode and displayed the information on the LCD in regular size.

Also, 'high' level of the auditory alternately provide buzzer sounds, high tone sounds and large voice message information that the driver can react quickly, and 'middle' of the auditory level repeatedly reproduces high tone sounds and extensive voice message information to provide. On this level, a message with a normal tone of audible hearing is provided. Finally, the 'Low' level of the tactile provides the driver with an interface for transmitting the vibration of the steering wheel/seat/ Seatbelt at a high frequency to the driver, while the 'middle' Provides an interface that delivers the right amount of strength. The "Low" of the tactile level conveys to the driver the interface that delivers the appropriate magnitude of vibration to the seat.

As a result of the analysis, the visual interface is more dominant than hearing in recognition, so visual information should be provided to the driver first in tasks such as signal band, speed operation, and night driving. However, in the case of the visual interface, there is a TASK in which the hearing and tactile interface should be given priority because the operating load felt by the operator is higher than other interfaces.

In this way, if the appropriate interface is selected and information is provided according to the characteristics of the driving TASK, safe operation can be performed while feeling less driving load than the driving driver, so that optimized interface such as visual, auditory, there is a need to investigate and study more in depth in the future.

Chapter 3. Cognitive Needs in Autonomous

3.1. Driving Behavior Transformation and Cluster UI

The driving behavior and the cluster UI composition has a close relationship. The development of the cluster composition reflects the responsibility of the human operator. It has evolved its functions and forms in matching the needs of cognitive information in driving. The vehicle user interface has evolved its functions and forms in matching the needs of cognitive information in driving.

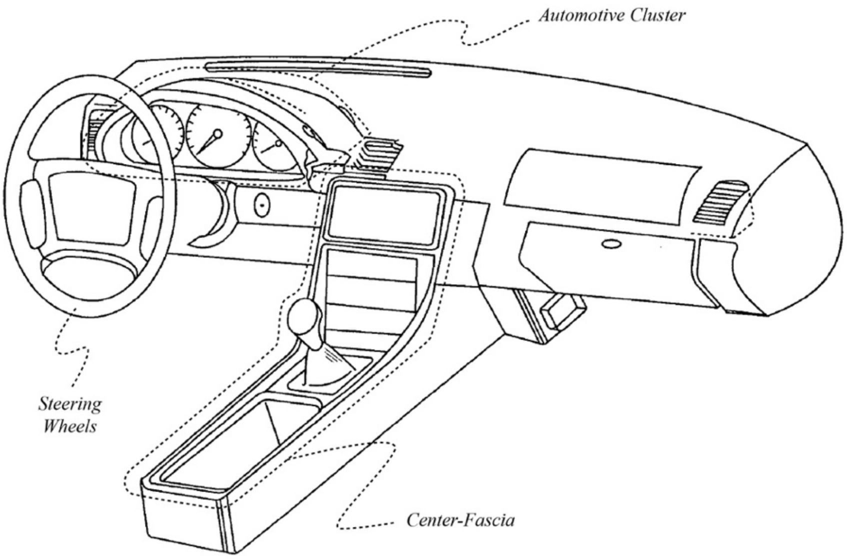

Figure 7. Described image is the Automotive Dashboard. (Reference image retrieved from pinterest.com)

Dashboard is a panel laying across the interior of a vehicle which locates in front of the driver's seat and usually containing instruments and controls[25]. As shown in Figure 7, dashboard is an aggregate of informative and control elements such as cluster UI and center-fascia[26]. It provides information that the drivers need to review while driving. Center fascia element usually contains environmental settings such as audio control, air conditioning and in modern case, a navigation. The mechanical state review is given through Cluster. Cluster screen is also called as an instrument board. It contains information that is directly related to the vehicle state such as speedometer, Fuel Level Gauge, Center Fascia, gear lever, and Rate Per Minute instrument as shown in Figure 8.

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[25] "Dashboard." Def.2. *Merriam-Webster.com*. Merriam-Webster Dictionaries. 18 Nov.2018

[26] Morello, L., Rossini, L. R., Pia, G., & Tonoli, A. (2011). *The Automotive Body Volume I: Components Design*. Dordrecht: Springer Netherlands.

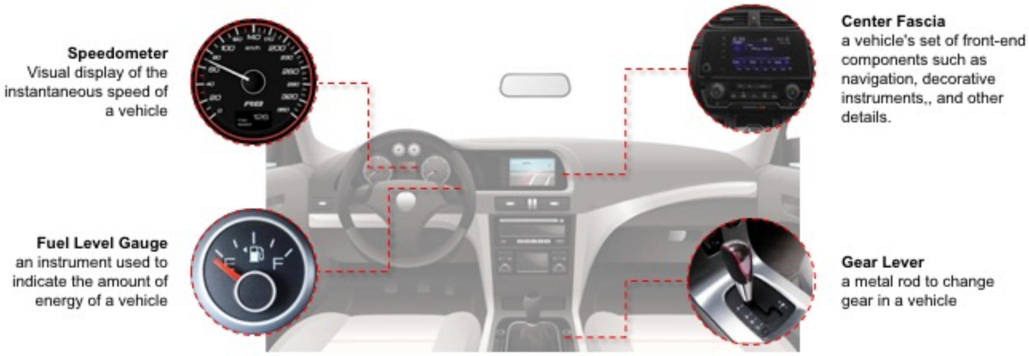


Figure 8. Four representative features that relate to the vehicle condition: Speedometer, Fuel Level Gauge, Center Fascia, Gear Lever.

The history of the modern cluster UI manifests a close connection with the development of the vehicle machinery. The early automotive cluster provides the machine-centered cognitive information. The pure reflection of the mechanical state was the cluster UI's primary role. A good driver means a user who can control the vehicle in consideration of the mechanical state.

The concept of modern dashboard is formed in 1908 as Ford's Model. The early concept of car was a wagon with an engine. With the Model T, the car starts to act as a separated spaced with ceilings and closing door. And as the engine capacity gets bigger and a safety problem has occurred due to speed in the early 1900s, the speed limit has been determined by the law. Speed control has been added to the simple start/stop configuration. In 1902, a German engineer, Otto Schulze, developed a speedometer using Eddy current, which allowed the driver to control the vehicle at the specified speed. In 1910, the Ford introduced Model T with a dashboard on the driver. As it is shown in Figure 9, the early formation of the panel was arranged with the speed and gear gauges in the center, a clock, a mileage gauge and a fuel gauge on each side.

Figure 9 Dashboard arrangement of Ford Model T, 1910

As the major manufacturers include Ford adopted the speedometer as a standard equipment, the dashboard formation as shown in Figure 9 is fixed as a tradition.

The development of cluster UI over time is well described in the Knoll's journal 2017. He arranged the representative evolution in graph as shown in Figure 10[27].

[27] Knoll, P. M. (2017). Some pictures of the history of automotive instrumentation. *Journal of the Society for Information Display, 25*(1), 44–52. doi:10.1002/jsid.536

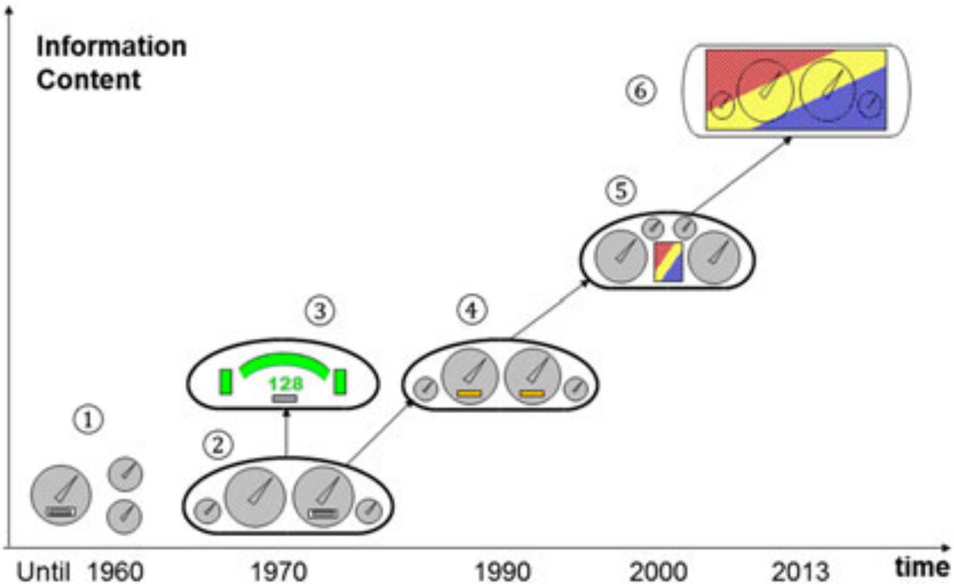


Figure 10. Cluster UI transformation from 1960 to 2013 by Knoll. The graph indicates the feature evolution of cluster screen (Source: Some pictures of the history of automotive instrumentation by Knoll, P. M.).

Starting in 1930, other gauges and functions, such as engine revolutions (RPM meters), fuel gauge, and turn signals, were implemented together on the instrument cluster. Growing Traffic and the extension of roads were the main factors for gauge implements to raise the awareness of the vehicle condition. In 1950, a guiding method using an electric signal was introduced by breaking away from the mechanical axis-driving method. In 1980, a totalizer system using a stepping motor was added and a display method using an LCD. Until 2000, the composition of the cluster was an analogue with physical needle. It was simple and low-cost but often inaccurate and gets broken in short amount of usage. In early 2000s, a LED digital gauge was adopted. The method had longer life-cycle and able to lights up during the night. It provides better user interface with focus. All-electronic dashboards using sensor signals have been developed, and various functional dashboards as TFT color systems, HUD systems, and instrument panel reconfiguration systems have been introduced. A variety of display visualization has been studied to optimize driver cognition.

Evolution to the smart car brought a major transformation into the user interface. The screen is expanding and the interaction with the touch screen is widens. The voice communication is adopted, and the data processing gets fast. There were more of an intangible interaction than the physical button to input the vehicle. As an evidence, the clear division in function between cluster screen and center-fascia gets vague. Like the Tesla's UI most of the information such as route is given through one single screen on the center. The additional specification of a driving process is given through the cluster screen in the center area. The center-fascia and cluster screen share the function and the purpose.

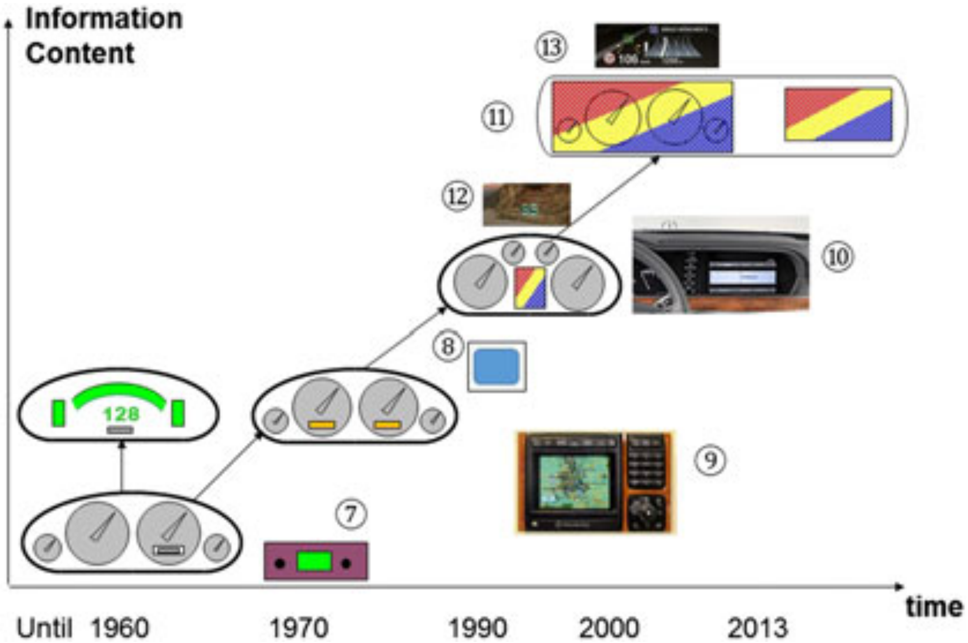


***Figure 11. The graph indicates the development of center-fascia in relation with cluster screen interface - the division between center-fascia and cluster screen become vague (Source:** Some*

pictures of the history of automotive instrumentation by Knoll, P. M.).

The features are united and simplified. The capacity of single screen grows, and the mechanical control is become the task of the system, the driver's task is very minimized. The required role that used to be was a reviewing the information through the dashboard and controlling the steering wheels and peddles. The concept of the vehicle becomes connected and smart. Naturally, the role of driver will be minimized and reduced. This is how the driver becomes passenger. Then, what would be the responsibility that is left for passenger? And what kind of information that they need? Study on this matter is how to direct the future mobility.

3.2. Cognitive Framework Transformation

As for the AV, the data flow changes, as shown in bottom side of Figure 13. The intervention of the driver is unnecessary. Based on the premise that the car (the system) is capable of all driving tasks, especially starting from level 4 automation, where the system is capable of executing all driving tasks and decision making, the system becomes the center of the main data flow. The 'driver' becomes the 'passenger,' who carries cognitive abilities and needs relevant to situational understanding. In that circumstances, two research questions arise: would the passenger request any information from the system and would the passenger desire to reflect any preference?

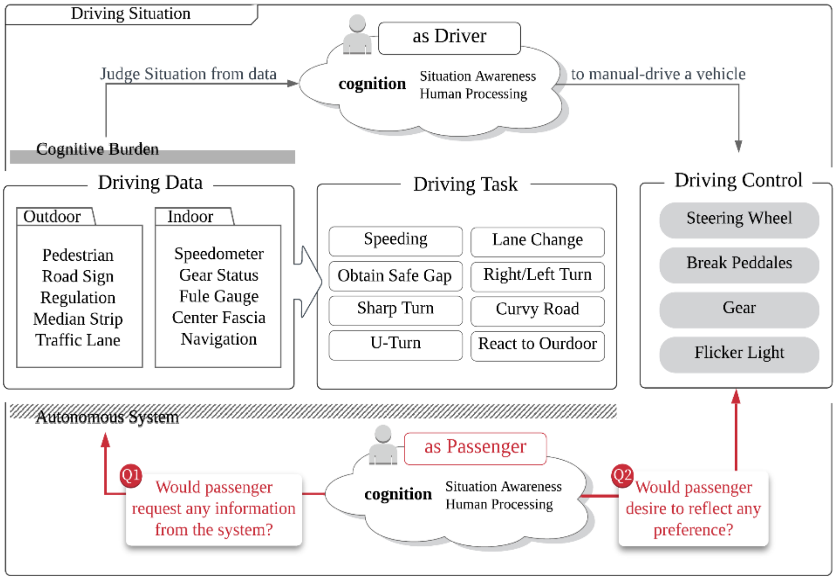


Figure 12 The cognitive framework of Autonomous. The data flow and the human operator's role are changed in the autonomous situation. The car directly perceives the data and handles the driving tasks, but the driver still has the cognition ability. In the changed data flow, the thesis question arises.

In Endsley's research (1999), the human operator showed a willingness to review the system's activity and to be involved in the system's decision-making process. Adapting this study to a driving situation, the monitor that displays the system's activity corresponds to the cluster UI. Extant studies have analyzed the user's perspective in driving situations. Lee (1996) examined the relationship between a driving situation and driving behavior. Choi et al. (2010) analyzed the overall task in a given driving situation and suggested the most suitable cognitive direction for each task. However, few studies have collected empirical data from a passenger's perspective, especially in a personal vehicle driving situation. The driver's cognitive state and the tasks have been identified in detail as they are directly related to safety, but the passenger's state of mind is not critically considered. AV will dramatically change the mobility culture. Understanding the passenger’s perspective helps to lay the foundation needed to accept the new mobility.

The current cluster UI is designed from the perspective of the driver: the data that the driver needs to review while driving, as well as the mechanical data they need to control. Then, when they are exempted from the burden, the cluster UI in AV needs to be decontextualized from the perspective of the passenger. Whereas the driver’s cognitive capability was primarily used for advancing tasks as described in Figure 1, the passenger’s cognition expands to review overall system activity and to assist in improved searches.

Understanding the context and the situation in AV is the fundamental goal of this study. Therefore, the passenger’s requested information and reflection of preferences in the system are the two research questions addressed in Figure 13.The gradual change of the data flow and the human operator’s role changes the relationship of data, human and the vehicle. In comparison to Figure 6, the Cognitive Framework in Manual Driving, The human operator is not required to be included in the data flow as shown in Figure 12. However, the human still is the main subject of the mobility and still have intelligent cognitive ability.

To objectively understand the passenger’s perspective in the designed data flow accordance to Figure 12, three sets of user tests are planned in the simulated autonomous environment.

Chapter 4. User Tests

In order to articulate the desired information elements, observing the user-centered feedback in the autonomous is necessary. A user experiment was conducted to observe the desired cognitive information in the perspective of the passenger. The main point of the experiment is to build the cognitive model from the perspective of a passenger by observing the information type that they seek to know. There are several studies on driver's cognitive model, but insufficient research was on the status of the passenger, especially in the autonomous situation. Thereby laying the foundation for accepting new forms of mobility with confidence.

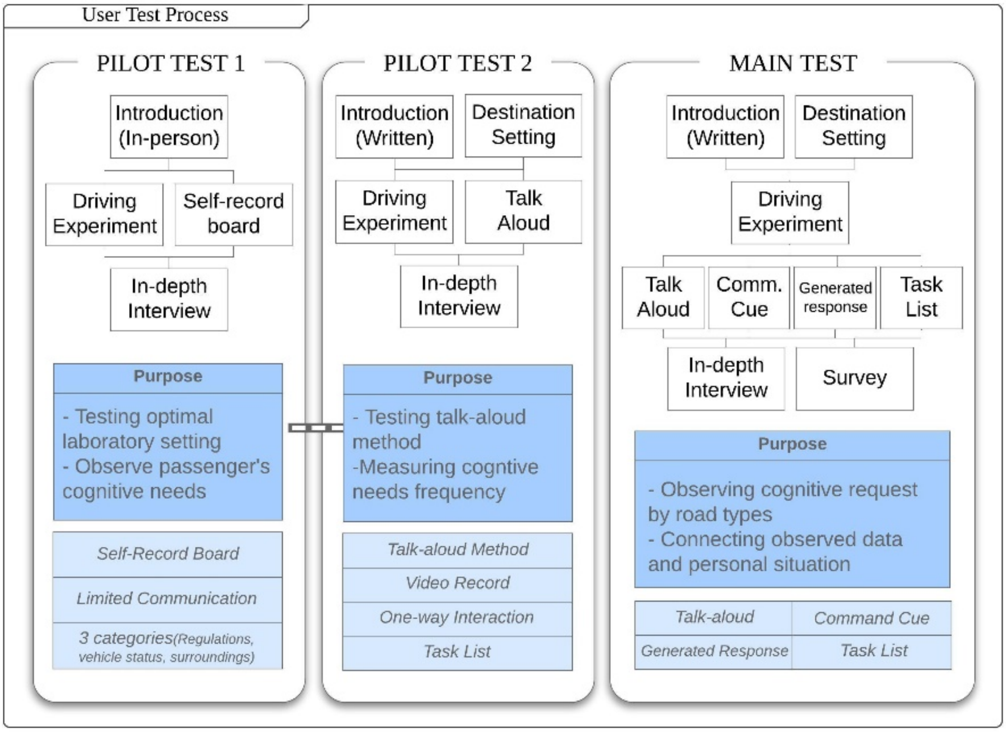


Figure 13 User Test Process: Pilot Test 1, Pilot Test 2, Main Test

Three sets of user experiments are designed: Pilot Test 1, Pilot Test 2, and the main experiment, controlled under a laboratory setting. The process of user tests is mapped out, as shown in Figure 13. The entire procedure is the repeatable process for establishing a detailed laboratory setting and observation methods. As the test is repeated, the length of the simulated drive is extended, and the level of communication between the system and the passengers is elevated to elicit active feedback. 6 passengers participated in Pilot Test 1 and Pilot Test 2, and the pain points from the experiments were utilized as critical for planning Main Test strategy.

All user tests were conducted in an actual car and on the real road. The laboratory setting was designed following the Wizard of Oz (WOZ) prototyping method. Three initial guidelines are set for the laboratory setting: limited human interaction, privatized passenger's seat, and completely blocked pre-setting informational resources. Limited human interaction is for observing request from participants, privatized passenger's seat is for providing driving-alone atmosphere, and complete veil of all the pre-setting informational resources such as navigation, direction blinker, and any other operational sound is for observing cognitive information request in the information-free environment. The laboratory setting was designed to convey the passenger experience rather than deliver an exact replica of autonomous driving.

The purpose of the tests is to collect enough empirical data related to the passenger's cognitive needs in the simulated autonomous situation and to answer the two research questions. Further, proposal of the UI design for the passenger based on the future user scenarios is the result of the study.

4.1. Wizard of Oz Prototyping

In autonomous, the cluster rather need to focus on what the passenger desire to know. Rather than what they need to know. Knowing what kind of cognitive information of a passenger is the crucial pillar to design the cluster UI for autonomous. However, the Autonomous vehicles is not yet in reality, so the experiment needs to be the careful simulation of the real autonomous to observe the behavior of a user- which is the passenger. The purpose of the simulation is to give enough feeling of passenger than exact replica of autonomous.

A user experiment is needed to understand the passenger's perspective and their cognitive needs. There were two concerns about the experiment. First, how to simulate the autonomous- like environment? The autonomous technology is not entirely in everyday life, and there is the limited possibility to proceed the experiment in real autonomous car. To observe the Passenger's real reaction, it was the key to simulate the driving-alone like situation. Second, how to drag many cognitive needs from the participants? If the participants are driving along during the experiment without any reaction, there would not be much to observe. More reaction, the better. For making the further connection from the raw data.

The Wizard of Oz Prototyping (WOZ) is used when designing a system or a program's interface that is not yet exist[28]. It prepares task scenarios for the purpose and function of the system and applies Prototyping to derive more advanced results for users. The technique involves both shadowing and prototyping.

[28] Bernsen, Niels Ole, Hans Dybkjær, and Laila Dybkjær. "Wizard of oz prototyping: How and when." *Proc. CCI Working Papers Cognit. Sci./HCI, Roskilde, Denmark* (1994).

It requires two computer system roles. One is the Facilitator, the other is the interface, and the other is the Wizard. Experiments are carried out by a person who acts as a Wizard, Human Operator, on the Behind the Screen around the user. Human Operator allows each task to function as a system or service that provides rapid prototyping required for the situation. The Wizard will properly provide the prototyping elements needed to carry out each task, such as pulling the lever or touching the switch on the back or side of the experiment space. Wizard is a member who can talk to the user smoothly about the system or service.

In particular, if the user manipulates the interface of a specific system or program that the user has not experienced, the Wizard can create and display the interface result, and if the user has various query attributes for the search, it also writes sentences of the type related to the question or hand-selected search results. Similarly, the WOZ method can also test general natural language interfaces. For example, the results may be extracted through which Syntax (statement) was selected to supplement the system or service and which Syntax (statement) was selected and used during the actual test. (You can use this method if you want to test the hypotheses studied by participating in the experiment, or to show the results of the formalized questions.)

Preparation of Wizard of Oz Prototyping needs 1) Participant (User) Recruiting, Facilitator, Wizard; 2) Schedule & Testing-Room; 3) Prototype. For the WOZ, range for the experiment, design the task, and recruit the user suitable for the experiment is needed. Obtain Insight by observing and analyzing user behavior through report result. Repeating the experiment to improve the process and meet the needs of the user as much as possible.

In the WOZ technique, it is possible to obtain more advanced results by repeatedly experimenting with prototypes, and by using the improved process, it is possible to meet the needs of the user as much as possible, or to imply that the scope of problems found through observation is a core part. It is a method to solve the problems of each situation through repetition of experiment and to derive the developmental result.

4.2. Pilot Test 1

Pilot test 1 was prepared and tested on three participants. The experiment has proceeded in the real car and the environment was plain. By placing a partition and covering every cluster and center-facia UI. The participants, the passenger, were given the task order and the commander list. Task order provides the basic communication tasks during the driving. If there are any other needed information, they can say it out loud with the command cue. Only with the commander list, they can reflect their wants in the driving. There are four types of road conditions: urban road, Inter-Sections, highway, and traffic. The duration of the test was 30 minutes for each participant. The entire Experiments were recorded on camera, and a post-interview was given for more profound observation.

4.2.1. Experiment Design & Laboratory Setting

A user experiment was proceeded according to the design prototyping methodology of Wizard of Oz. A future lifestyle in the assumption of L4 autonomous is articulated, and observation on the type of desired cognitive information has proceeded.

Table 3. Framework of the User Experiment to observe User-Centered cognitive information in Autonomous.

Title	Context
Purpose	A qualitative study on the cognitive needs that the passenger desires
Expected outcome	Different type of cognitive needs/ different priority of information compare to the current UI does not provides
Experiment method	Wizard of Oz, in-depth interview
Materials	Persona Task list Self-record board In-depth interview Questionnaires
Roles	Human Operator: perform virtual autonomous driving Participants: fit the persona under the assumption of riding in the real autonomous vehicle. recording on self-record board and in-depth interviewing after the experiment

The purpose and the function of the system is identified in Table 3. The scope of the experiment is observing the Passenger's needs in driving situation. The participant carries out qualitative research on "required" information and "perceived" cognitive information. Simulation of the Autonomous is not the main purpose of the experiment, but to drag out the as many cognitive needs as possible under plain setting where the passenger drives by themselves.

4.2.2. Persona Scenario & Task Design

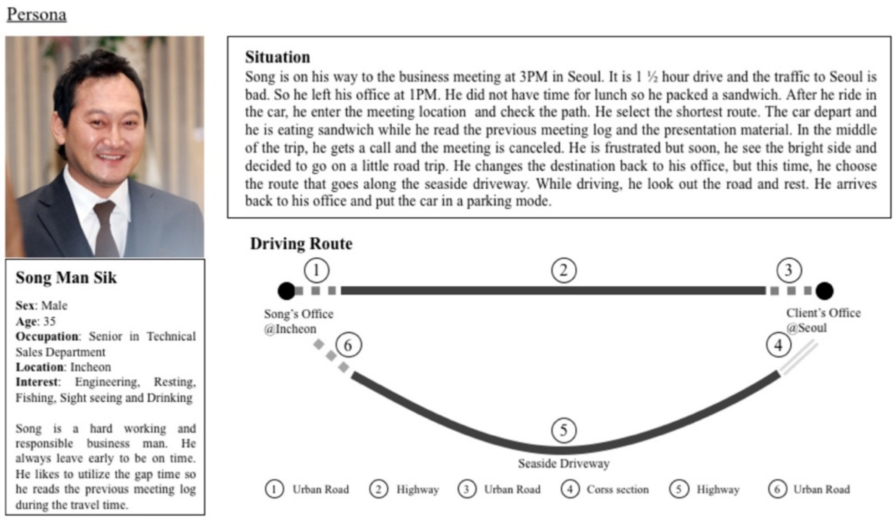


Figure 14. Persona board and the driving situation

The representative persona of the experiment is Song Man Sik as shown in Figure 14. He is 35-year-old, a senior in the Technical sales department. His company located in Incheon and he lives 30 minutes away from the office by driving. His interest in engineering, resting, fishing, sightseeing and drinking. Song is a hardworking and responsible businessman. He always leaves early to be on time. He likes to read during the travel time; usually it is meeting logs or presentation materials.

Song is on his way to a business meeting at 3 PM in Seoul. It is 1 ½ hour drive, and the traffic to Seoul is terrible. So, he left his office at 1 PM. He did not have time for lunch, so he packed a sandwich. After he rides in the car, he enters the meeting location and checks the path. He selects the shortest route. There is three type of the roads on the route: urban road, highway and cross section. The car departs, and he eats the sandwich while he read the previous meeting log and the presentation material. In the middle of the trip, he gets a call, and the meeting is cancelled. He is frustrated, but soon, he sees the bright side and decides to go on a little road trip. He changes the destination back to his office, but this time, he chooses the route that takes D-tour along the seaside driveway. While driving, he looks out the road and rest. He arrives back at his office and put the car in a parking mode.

A list of tasks order based on the proposed driving situation is provided to the participants as shown in table 4. It is utilized as a guideline of the procedure: the participants are free to add or omit the particular task at needs.

Table 4. Wizard of Oz-User Experiment task order.

Task	order
Destination setting to the business meeting location	1
Driving route check	2
Speed adjustment	3
System status briefing	4
Resource material review for the meeting	5
Getting a call	6-1
Mute system	6-2
Destination change	7
Search for the d-tour route for seaside way	8-1
Select the route	8-2
Communication with system	9
Arrive	10
Getting off the car	11

Put the car on a parking mode	12

A marker and a pack of post-it are provided. On the self-record board, there are three categories of information types: situational, vehicle status, and driving route as shown in Figure 15 and Figure 16.

Figure 15. Self-Record Board (Korean Version).

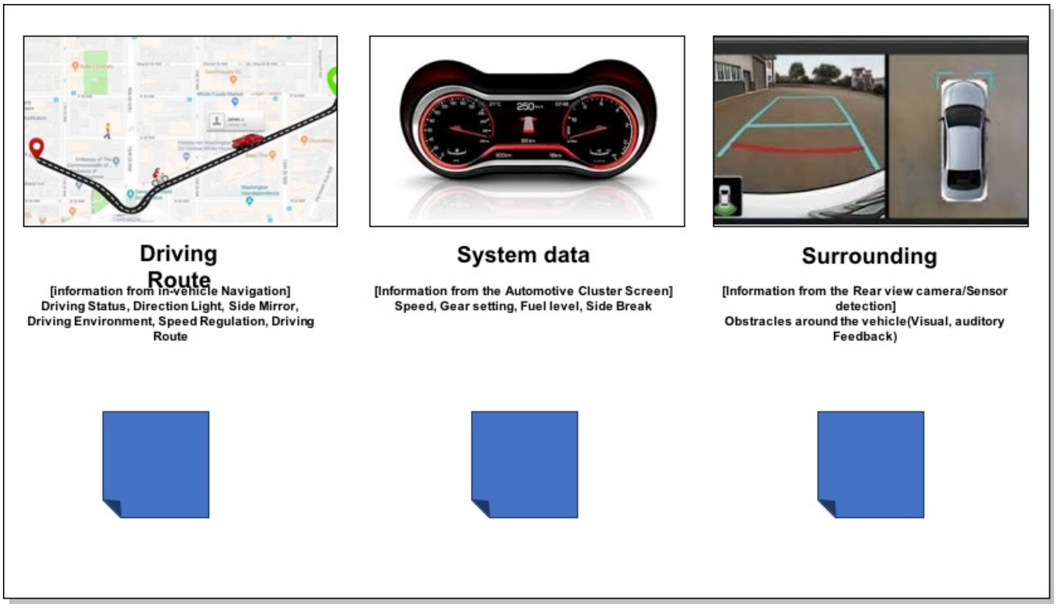


Figure 16. Self-Record board (Translated in English). The Self-Record Board that provided to the Participants in the Pilot Test 1 were in Korean.

4.2.3. Preparation of Driving situation

Based on the fabricated persona and the driving situation, the user experiment proceeded. The virtual autonomous driving environment is established by installing a partition between the operator and the participants as shown in Figure 17. The experiment operated by the human driver but to simulate the automated atmosphere as close as possible, the two-way communication is banned. The passenger can talk about his / her impression in the state of self-talk, and it is conducted as a critical observation point. The operator wears earplugs to block the existence of the operator as possible.

Figure 17. initial laboratory setting of the Pilot Test 1.

Figure 18. Participant's position with the Self-Record Board.

A Self-Record Board is placed in front of the participant to record their live feedback during the experiment as shown in Figure 18. Following the Song's situation, the driving route of the experiment is the combination of the following three types of roads: An Urban road with pedestrians, a highway where pedestrians are restricted, and cross section with traffic.

4.2.4. Procedure

There are three participants as shown in Table 5. The only participants with driving experience are selected based on the assumption that they have the better understanding of the type of cognitive information needed on the road. Participant 1 had 30 years of driving experience and also experienced with a partially autonomous car. Participant 2 has driven for ten years and also a partially autonomous car once. Participant 3 do not have a autonomous experience but have 31 years of driving years. The participants were instructed about the base premise of the experiment, the persona, and the articulated autonomous atmosphere.

Table 5. The Participant's Driving related information.

	Year of Driving	time of Procedure
Passenger 1	30 years	5PM
Passenger 2	15 years	6PM
Passenger 3	31 years	7PM

They each road in the simulated autonomous for 20 minutes and 10 minutes for the in-depth interview. While the driving, their reaction and the facial expression were video recorded and used as a reference for the interview. The participants could express their reaction or emotions out loud, however, the communication with the human operator is strictly limited. While they participate in the test, they recorded their cognitive needs on the self-record board in real time. The in-depth interview was based on their self-record board to analyze the desired cognitive information from the viewpoint of the passenger and construct the cognitive model.

4.2.5. Data Analysis & Insight

The participants write their feeling and feedback one item on each post-it. They were sorted into three categories: situational, vehicle status, and road situation. If a specific feedback composition of two categories, it was posted in between the system. Figure 19 is the resulted self-recording board of the three participants after the experiment. Based on the board and the video records, an in-depth interview was followed for each participant. Table 6 is the highlighted quote from their interview.

Figure 19. (Left) The self-recording board after the simulated self-driving of Participant 1 and 2. (Right) The self-recording board of Participant 3. The participant writes their feedback on post-it during the experiment, and sort them into three categories of information types: situational, vehicle status, and driving route.

Table 6. In-depth Interview Log

Participant	Emotional status	Feedbacks
Participant 1	Anxiety Overall Feel Cabin Fever for not being able to communicate with the system directly Fear of accident caused by other cars	"I feel more confident and taking control when I am driving by myself." "…I wanted to predict the next movement of all other cars/pedestrians around my vehicle." "I wished to know the driving direction of the vehicle." "I feel … physical comfort deviated from the act of driving." "There were some moments where I wish to drive more closely with the car in front of me."
Participant 2	Anxiety Feel Cabin Fever for not being able to change the vehicle status	"I did not want to take over the control … however, wish to speed up and down." "I would be better if the system answers to my reaction or questions." "The preannouncement before the system reacts to anything like the changing direction or stop or start would be crucial." "when there was a motorcycle pass by the car, I was afraid if the system senses the obstacle." "the live feedback on the vehicle location … I constantly wish to

		know the current location on the driving route.”
Participant 3	Feel Cabin Fever for not being able to speed up Hollow feeling for losing the right to control	“The car drove to slow in the empty road … if I were driving, I would speed up more … even over the speed limit if there was no speedometer camera.” “It was somewhat a relief that the system would cope with any obstacles instead of me.” “Unexpected Obstacle like running pedestrian and cutting in threatened me … more severely when I am driving.”

The three main problems were vivid from the experiments; there was the absence of communication with the autonomous system, there was low trust on the other vehicles on the road, and the vehicle fails to reflect the participant’s preference. For the absence of communication with the system, the participant wishes to know the vehicle’s next movement, direction, and the path. Since the steering wheel, navigation and the direction blinker were concealed, the frustration to predict the movement was strong.

Another problem was the low trust in other vehicles on the road. It was interesting because the distrust was on other manually operating cars, not the automated system. The participants had a solid trust in the autonomous technology itself based on the premise that it is capable of all driving tasks. They answered that riding in the autonomous would be safer than driving themselves because the technology overcomes the human cognitive limits. However, they also responded that they do not feel comfortable because people drive the other cars. If the cars around the autonomous do not make the same mature decision that the system could, it is untrusted even though the autonomous car drives under the regulation. Hence, they feel more comfortable when they can react to any incidents for themselves. The other problem is that the system does not reflect the participant's preference such as speed and gap between cars. The simulation followed the regulation precisely and kept the constant distance from the car ahead without a tailgate. However, speed and tailgate are varied on the traffic situation and the passenger's preference. The participants wished to reflect their preference on the speed change and distance between the car.

4.3. Pilot Test 2

Based on the observation from Pilot Test 1, another test was given to different participants. The previous participants were experienced drivers with 30+ years. They had their own style of driving and very confident about their driving skill. Therefore, the main feedback from the participants where they feel more comfortable to drive by themselves and having a 'system' feels likes taking a second channel to reflect their needs into the driving. The communication issue was a shadow before the observation on passenger's needs. Therefore, in Pilot Test 2, the communication method between the participants and the system were tested and the task list were redesigned to draw more of the requests during the drive.

4.3.1. Amendment: Experiment Design & Laboratory Setting

The purpose and the expected outcome remain the same. However, the communication method when the participants input their needs in the first pilot test showed a clear limitation. Therefore, the Command cue has been added to the procedure. Command cue helps the participants to directly input their needs and promotes the feeling of riding in a system controlling vehicle. As the participants talk-aloud their information needs, a video recording replaced the self-record board. Along with the command cue, the task list is refined in more detailed way and information-centered tasks are added to the first draft.

Table 7. Refined Pilot Test Structure

Title	Context
Purpose	A qualitative study on the cognitive needs that the passenger desires
Expected outcome	Different type of cognitive needs/ different priority of information compare to the current UI does not provides
Experiment method	Wizard of Oz, in-depth interview
Materials	Persona Task list Command Cue Talk-aloud In-depth interview Questionnaires
Roles	Human Operator: perform virtual autonomous driving Participants: fit the persona under the assumption of in-vehicle alone. Talk-aloud

	their information needs regarding driving issue.

The visible change on Pilot Test 7 is the material. The Self-Record board in Pilot Test 1 is replaced with Command Cue and Talk-aloud method. In this way, the passenger is able to put their needs directly and heighten the feeling of interactive and smart system.

The refined Persona describes more details profile of a character and a driving situation. The scenario focuses more on the daily driving situation instead of one particular occasion. The persona helps the experimenter to think about the driving position as an actual autonomous driving environment and helps them to immerse and to perform a given task more naturally.

Persona of Mo

Demographic information: *35 years old, currently attending graduate school at the company.*

Occupation: *5-year database technology salesperson. Work at Seocho-dong company from Monday to Friday and go to graduate school at night every Friday. Due to the nature of B2B sales work, there is a lot of work and a lot of drinks. Did not have time to be on vacation this summer yet.*

Goal: *Maintain friendly relations with customers, advance to next year, master's course*

Situation: *5th-year junior employee, including senior manager and manager, belongs to a team of about ten people, 5th year but there is no junior, the team keeps earning a severe performance*

Technical expertise: *interested in new products and new technologies with the belief that 'Machines are always new'. Not a gamer but an internet surfer.*

Hobbies: *Watch movies with Netflix, search for new products, post new product reviews on blogs, fit puzzles, write a diary*

History: *Mo grew up with a sense of responsibility as his eldest son, always kept the upper middle level and spent his school days. However, he was interested in computers and machines, and he was superior to other students. He also showed great talent in writing. During high school, he also played as a school representative in a local community competition. He wrote his diary daily and wrote mainly about what he learned that day and about new game machines or computers. Writing is Mo's oldest hobby, and observing new devices is the biggest concern. After entering college, he started to write a review about the electronic devices. He had interest in computer engineering and build the career in technical sales. Very few times was left for the blog with the career and the graduate school.*

Persona Scenario

Mo is a hard worker who always arrives at work on time. He is a person with his word and time. He lives 30 minutes away from the office but prefer to leave 30 minutes earlier prepare for the unexpected traffic conditions. He plans ahead and utilize traveling time for reviewing client meeting materials. Especially since he started his graduate program, he utilizes the travel time for presentation reviewing, searching for new products, and blogging wiring.

Pilot tests are conducted according to the persona set up for User Test. The purpose of the route is to test the performance of campus roads and intersections and to test the possibility of excavation and inspections.

4.3.2. Amendment: Task Scenario & Command Cue

In pilot test1, the purpose and the procedure steps were given by words directly to the participants. The introductory caused too much interaction between the operator and the passenger, which hinders from the complete immersion to the experimental situation. In Pilot Test 2, a packet of hand-outs was created for the better comprehension of the purpose and the process. It includes persona, driving route, task list and the command list.

The Task list on Pilot Test 1 mainly direct the task to setting the destination. To observe more cognitive needs while driving other than setting/ changing destination, tasks regarding information checking is added. As shown in Table 8, the purpose of the tasks is indicated in two categories: control and information checking. There are two kinds of reaction depends on the types of the request. If the request is for information, the system gives bib #1 and delivers information in human language. If the request is for control, the system gives bib #2 and changes the driving style according to the request.

Table 8 Refined Task List for Pilot Test 2

Order	Task
1-1	Setting destination
1-2	Information: Route Checking
2-1	Control: Start driving
2-2	Recognizing the drive
2-3	Information: Traffic check
3-1	Reading
3-2	Information: Location Check
3-3	Control: Change driving lane
3-4	Control: Speed change
5	Approaching to destination

6	Control: Input the Stop location
7	Getting off the car

While the passenger carries out the task list, they can communicate with command cue if the passenger desire for any cognitive information as shown in Table 9. The command always follows after the calling cue “Hey, Commander” to triggers the system reading and helps the operator get ready for the following command in the experiment situation.

Table 9 Command Cue for Pilot Test 2

Action	Cue
System Calling	Hey, Commander
Destination Input	Let’s go to (destination).
Start Driving	Drive off.
Route check	Tell me the route.
Traffic Check	Tell me the current traffic.
Change lane	Move to next right/left lane.
Speed change	Speed up/down. Drive at ## km/h.
Stop driving	Stop the car.
Change destination	Let’s stop by (name of the place). Change the destination to (name of the place).
Cancel input	Cancel the last input.

The trigger call cue is “Hey, Commander” and they can say their desired request after the cue. When they input the command, the system shows a reaction with a bib sound. For example, if the passenger wishes to change the lane, they can say; “Hey, commander, please change the lane to the left.”

The operator acts as an artificial intelligence system that performs driving. Real-time communication with the operator is limited to situations that are similar to real autonomous vehicles. However, you can use the Command language to reflect your preferences on your journey. The Command language is a way to enter the desired driving changes after a calling command to inform the operator of the start of the input, just like the operating system.

4.3.3. Amendment: Perform Role and preparation of driving situation

For pilot Test 2, the role of human operator is expanded. As described in Table 10, there are two roles in the experiment. Passenger’s task is to ride in the car and talk-aloud their cognitive needs. As they input their request using command cue, the operator manipulate the driving status and answer to the requested information.

Table 10. Roles and assigned task in Pilot Test 2

Role	Task
Passenger	Ride along Follow the task sheet Talk-aloud the information needs
Human operator	Driving Change driving statue according to the passenger’s request Bib sound play Search for requested information Answering the requested questions

Video recording of a whole experiment is installed. A partition around the driver's seat is installed to disguise the human operator and promote the feeling of drive-along situation. It was important to block the pre-installed information sources such as in-vehicle navigation, dashboard, or the turn signal blinker. Therefore, the in-vehicle navigation is blocked with a cover once the driving starts and the participants wears a specially made glasses with a side block as evident in Figure 18.

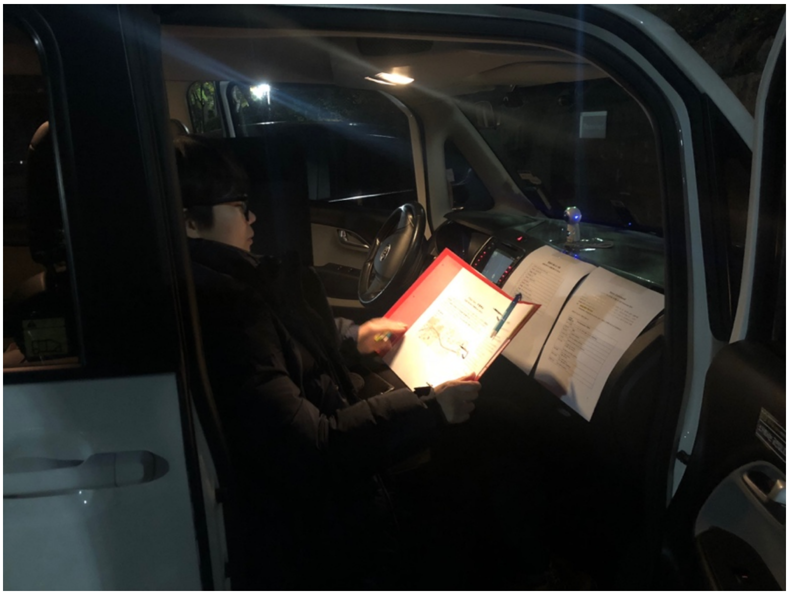


Figure 20. Experiment Setting. The passenger wears a glass with a side block.

Task list and the command cue is attached in front of the passenger's seat as a guide to follow as shown in Figure 20. A 360-action camera is installed to record the reaction and the road situation. The footage is utilized as an interview source for observing the reason of their request.

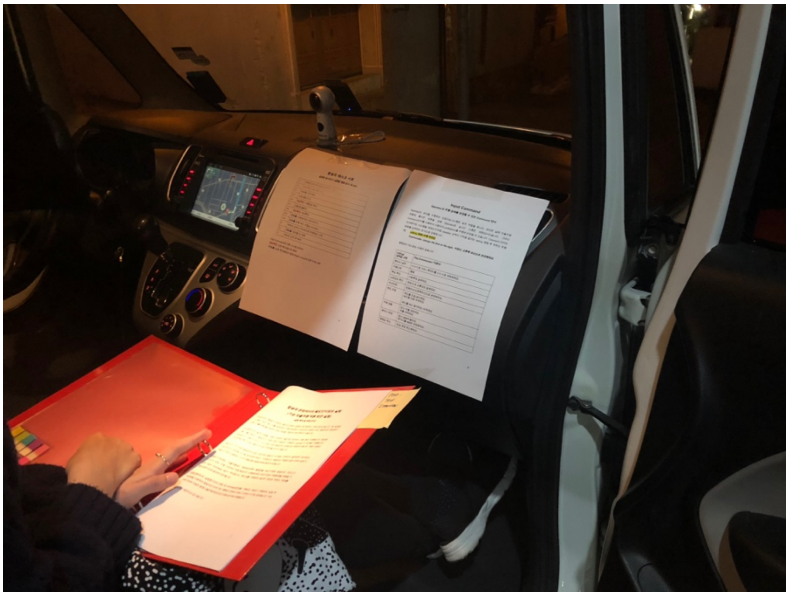


Figure 21. Passenger seat environmental setting. The task list and Command cue is attached in front of the participant's seat as a guide. A booklet is provided to the passenger to read while the experiment.

4.3.4. Amendment: Procedure

Three participants were recruited for Pilot Test 2 as shown in Table 11. Their age is in between 25-35 and the experiment was run after dark as same as the Pilot Test 1.

Table 11 Participants driving experience profile and Test schedule

	Year of Driving	Test time
Passenger 1	10	6PM
Passenger 2	8	7PM
Passenger 3	0	8PM

The Test time was on the similar time with the Pilot Test 1 in order to make a comparison between the result. Each participant's persona and driving style is observed before the experiment.

Passenger 1 drives every day to the work and travels every other week. His work is closed by his home, but he needs to drive to clients' firm. Driving is less tired than taking subway or bus. However, when he had to drink with the clients, taking the car is problematic. for most of the time, he calls a valet driver to his home, but it cost a lot and concerns him for the accident. He like to drive safe and slower than the regular speed because he thinks defensive driving is the best way to protect himself. He does not like to drive in Seoul because too much traffic and lane changing are a lot of stress to him.

Passenger 2 is a She is a Motorcycle rider. Her main mobilities are motorcycle, personal car and public transportation. She usually drives when she has lots of luggage and need to stay late in the school. Usually drives to the school. It is 15 min away, but the when she goes back it is the time when the traffic is bad. Parking is a big stress when she takes a car. When she drives, the always listen to the music, Bluetooth connected with her phone. The most attractive part of taking car is a fine audio that is installed in her car. The biggest disadvantage of taking car is when she has a drinking gathering. She loves to take a cup of beer, but it is not possible when she takes a car. When choosing a route, she prefers to choose the one with the least traffic rather than the shortest route.

Passenger 3 does not have a driver's license, but she often takes a taxi and a public transportation. She is more familiar to be a passenger than a driver. She likes to travel and visiting desert café but since she does not have a driver's license, she usually takes public transportation with her friends. It is a stress when the transportation is full of people without seats. She likes to drive (drive along) when she needs to visit place that is far away. The most concern when she drives along is the accident. She has low trust on other drivers that could be threat to her car.

When she rides the car, she prefers to control the environmental settings such as seat temperature or air conditioner.

Each participant is asked about their personal hobbies and situations that they drive in daily lives. An expectation from the drive and the most concern is also observed to make a connection between their original needs and test result. It may direct to a critical insight to understand passenger's perspective in autonomous.

Figure 22. Driving Route for Pilot Test 2.

The driving route for Pilot Test 2 is shown in Figure 22. The experiment takes a total of 30 minutes. It was a one-way trip from school of Sa-dang station as indicated in Figure 22. The route and the situation are given beforehand to the participants, but the recognition information about the running in the car is limited. It runs in a plain setting, and the passenger executes the assigned task and records the response in real time.

The route has high volume of traffic, roads with multiple lanes, going through a tunnel, also requires multiple lane changes. The route specifically set to observe the passenger's reaction and their request changes due to the multiple lane changes and high volume of traffic. The Pilot Test 1 was proceeded with low volume of traffic and there was a minimum request for speed change and lane change. By putting the situational variable in an opposite way, a comparison can be resulted for passenger's cognitive needs depends on the road situation.

4.3.5. Data Analysis & Insight

The observed data from the pilot test was analyzed, and the interdependent questions were asked to understand the passenger's perspective in depth. The relationship between traffic volume and cognitive needs was evident. When the traffic was smooth and the car drives fast and straight, there were few information requests, rather the passenger focus on the entertaining features such as listening to music or focus on the reading materials. The passenger responded to the questions regarding this behavior they felt safe and stable when the vehicle is driving at a certain speed. Relief and trust on the system's capability were the main factors of the passenger's indifference for cognitive information.

However, when the vehicle is at the congested sections, which means more cars on the road, they felt uneasy and worried about the possibility that other car might interfere with their safety. The most untrusted moment was when the car had to change lane on the jammed road. This makes the passenger feel they need to 'look over' the driving status and 'add extra eyes' on how the system handles the tricky driving tasks. The distrust on the system potential results in the check the surrounding of the vehicle.

One more critical reason for the passenger's action is the hesitation and expected arrival time. In the early stage of the driving, all four passengers asked about the estimated driving duration. The passenger has a strong need of knowing the time and the duration of the driving. They prefer to guess out the expected arrival time and the delay in the time is a disappointment. Therefore, when the vehicle is held in the traffic, it causes worry and irritation they need to spend extra time in the car than they expected.

There were two characteristics of the passenger's behavior; (1) passengers request information regarding driving route in a certain pattern, (2) passengers ask for certain information depends on the traffic.

(1) Driving Route checking pattern

It was observed that the order of information request to check the driving route at the beginning of the test was similar is patterned along with all three passengers. The passengers were given a list of tasks to perform during the test. They were instructed to set the destination and check the driving route. It was evident that the passenger requests extra information on the traffic estimated driving time and the current time.

A question about this pattern was asked in the in-depth interview whether the task list or the natural causes intended the order. The passenger answered the order felt as the reasonable logic process to understand the driving status. Passenger 2 responded that if the destination setting, route, and the traffic is provided together, it would be more preferable with fewer command lines.

(2) Cognitive request in relation to road type

When the driving route is divided into sections by road type, there are 6 sections: start(beginning of the drive), cross-section, traffic road, slow driving road, fast driving road, and arrival. Driving situation and the number of requests were highly related to the road type traffic and the driving speed. Road type and the passenger‘s cognitive needs could be categorized as shown in Figure 23.

Passengers tend to request certain information depends on the road type. For example, In the start section, there was a request regarding route and time. In cross-section, there was a piece of information checking regarding lane-change because of the traffic and direction of the route, location to check the remaining driving route, direction to find the reason for traffic and gap between the car when cutting in the lane. For the slow driving road, the lane change was the observed request. In highway and a fast driving section, the main requests were regarding speed control and the remaining driving time.

The most active request was in the arrival section. It required the most active engagement from the passenger because the destination setting does not reveal the specific stop location. Especially when the destination is set to a private building or to a vague area, deciding where to stop is tricky. Therefore, the passenger needed to direct the system to the appropriate stop location with a specific instruction. And this could be the most distinctive feature in autonomous interface compare to the manual driving.

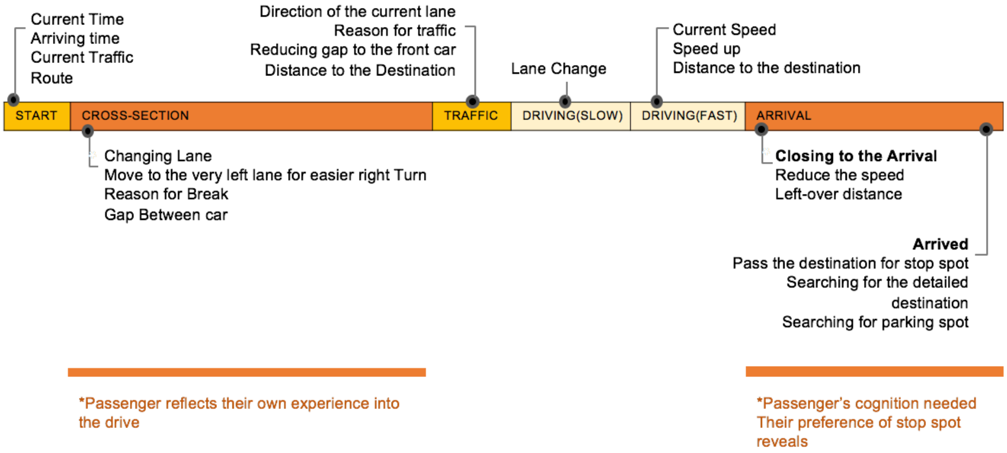


Figure 23.Visual framework of the Pilot Test 2 result. The Passenger's cognitive needs and the driving situation are linked.

The observed data from the Pilot Test 2 is visualized as a framework as shown in Figure 23. The bar indicates the road types and the width means the number of requests. The widest section means the greatest number of requests were observed during the test. As described in the framework, the cross-section and the arrival section are where the passengers felt the most needs of information. Passengers tend to reflect their personal experience in lane changing behavior. Especially when the passenger is familiar with the driving route, the frequency of the request grows to directly control the driving status. In other sections, the participants tend to follow the task list.

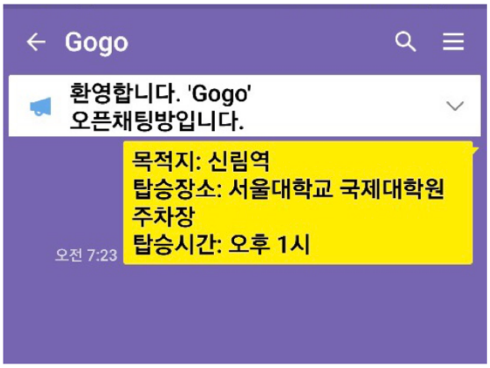
4.4. Main Test

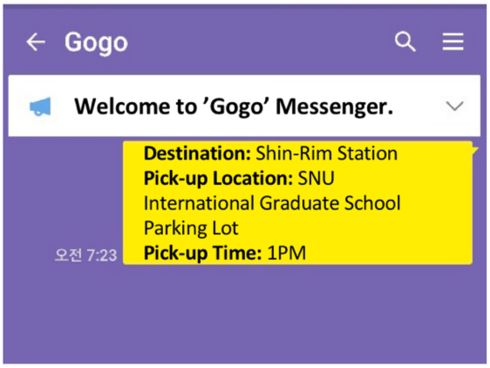
The main test was conducted on four different participants. Each passenger took part in the ride for one hour, and an in-depth interview was undertaken to gain more detailed explanations.

4.4.1. Experiment Design & Laboratory setting

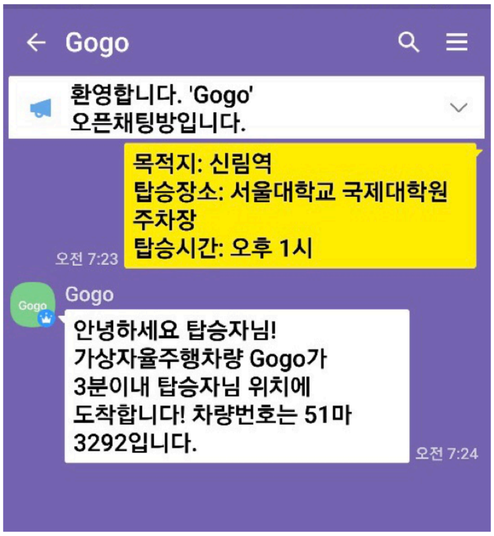
The one improvement on the experiment design and laboratory setting was about illuminate the human existence completely. To deliver the system-passenger driving atmosphere, the experiment materials and the purpose of the user test is handed to the participants 1 day before the test, so the passenger do not need any explanation in person. The boarding time is set prior to the test, and the passenger 'call' process is addressed blow.

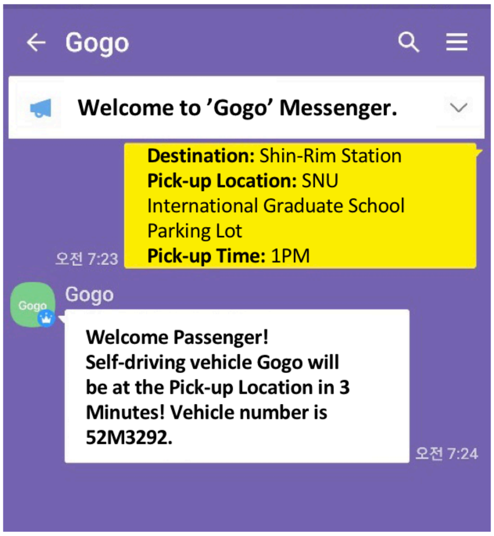
1. *Please contact "Gogo" via messenger.*
2. *Address the destination, boarding location, and time through the messenger.*





3. *A notification will be sent via messenger three minutes before the arrival to the boarding location.*





4. *Ride into the "Gogo"*
5. *Check the destination and the driving route.*
6. *Command to go.*
7. *If there is any information needed or wished to know, request them at any time with the command cue.*
8. *Arrival.*

For the convenience of the 'calling', the system is named as 'Gogo.' The passenger indicates the boarding location and the destination via messenger. 'Gogo' notifies the passenger of its arrival with the car number via the messenger as well. The message is formed as the automated message by the system. The passenger board on to the car without a single human interaction.

The purpose of the 'Gogo' messenger was to generate the communication channel other than the human voice. Texting provides inhumane communication experience. Implication of 'Gogo' messenger is to eliminate humane aspect of the experiment. The existence of the human operator could not completely disguise, however, restriction of communication and providing another channel of communication method promoted the feeling of system generated driving environment.

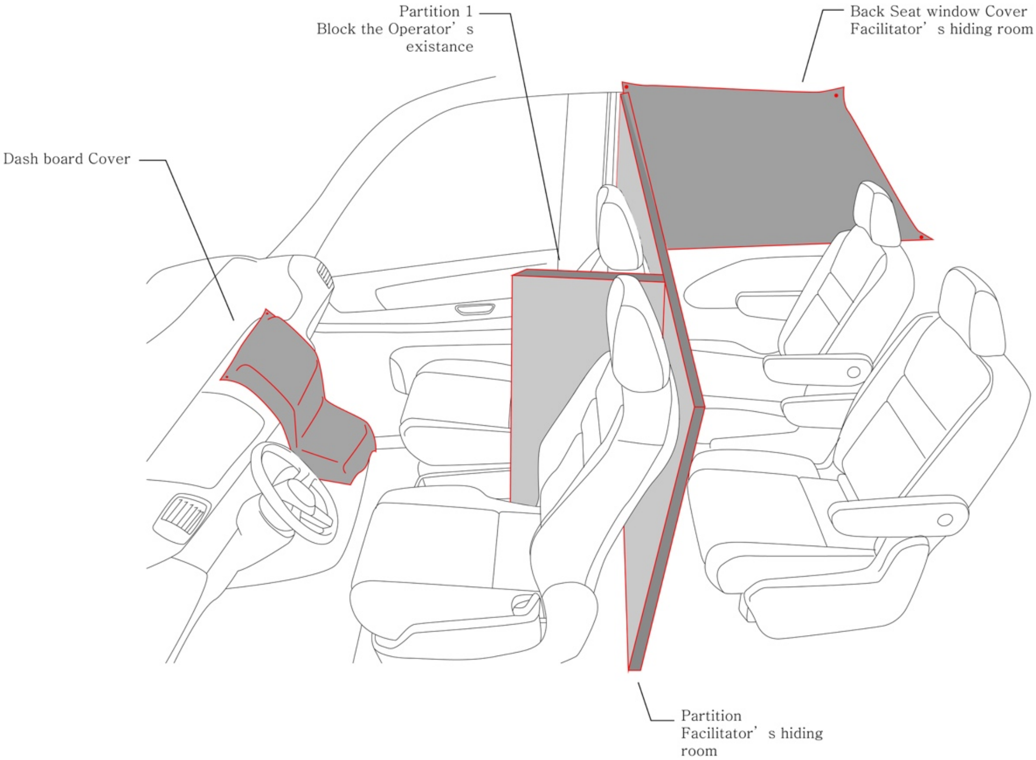


Figure 24. Experimental Set-up for the Main Test. All the in-vehicle information source is covered. The Facilitator seat in the hidden room on the back to provide requested information by the passengers.

The user test environment is divided into three parts: the operator's seat, the participant's seat and the facilitator's room, as shown in Figure 24. The operator was prohibited from expressing any response other than performing the driving task. The facilitator creates the response to participants' needs using an automated voice, a Bluetooth speaker and a laptop in the back seat. The center-fascia, the dashboard, and any other in-vehicle information resources are covered. It was important to expose the passenger in the plain setting where any kind of information is strictly eliminate in order to observe their informational needs. The requested information from the participants and their curiosity related to driving status are considered as critical clues.

The whole drive was recorded using 360-degree camera. It records the road and the reaction of the driver. It acts as a reference when collecting behavioral data and interview data. A copy of the command list and the task list are attached in the front dashboard for the participants. A tablet PC is set up for on-line survey that the passengers are able to record their reaction in real-time. The passenger's seat is designed to be completely isolated for better autonomous driving experience.

The back seat is completely covered with the partition and window cover. It is a hidden room that for the facilitator to responds to the passenger's request. The area is set up with the task sheet, command list and a computer. The computer is connected to the in-vehicle sound system with Bluetooth. According to the passenger's request, the facilitator generates the answer via computer and announce it as if the system responses.

4.4.2. Task Design

In the Main Test, there are three roles: Passenger, Human Operator, and Facilitator. For each role, the seating location and the tasks are addressed in Table 12.

Table 12. location and Tasks for each role in the main test.

Role	Location	Task
Passenger	Front seat	Ride in Real-rime survey

		Information request with command cue
Human Operator	Driver's seat	Drive the car
Facilitator	Back seat (Hidden room)	Traffic informs Route informs Requested information generating

The passenger seats in the front seat because the tested driving situation is on the base premise that they are ride in the system-controlled vehicle. They need to take a look at the traffic and the road situation if they wish to. Therefore, the front seat is proper for reviewing the road. The task of the passenger is to ride in the car, fill out the survey through the screen and request for the cognitive request using command cue.

The human operator act as a system and seats in the driver's seat. The operator is de-identified with the muted color clothes, a hat, sunglasses, gloves and a mask. It was the purpose of stating that the human operator is just act as a system. The main task of the human driver is to drive. There is no human interaction with anyone. The existence of the human operator is minimized as possible.

The facilitator has the most important task in the test to generator the requested information. The facilitator is the person who fully understands the experiment and is able to manipulate the whole situation. In the test, the facilitator used google translator for generating machine-voice, the laptop to searching web and in-vehicle Bluetooth speaker. When the passenger request for an information, the facilitator generate the proper responds with the translator according to the request.

4.4.3. Procedure

The four participants were recruited for the main test. The recruitment is arranged in the pool of participants who understands AV technology as shown in Table 13.

Table 13. Test Schedule for each passenger

	Year of Driving	Test Schedule
Passenger 1	1 years	Nov.14 10AM
Passenger 2	10 years	Nov.14 12PM
Passenger 3	16 years	Nov.14 3PM
Passenger 4	0 years	Nov.14 4PM

The boarding time for all passengers were scheduled beforehand, and the schedule was informed through the 'Gogo' Messenger. According to the schedule, the passenger calls the car to their location and the arrival time is informed through the messenger as shown in Figure 25. It is the device to block in-person interaction and to provide the controlled system interaction throughout the main test. All the communication and response were machine-generated.

Figure 25. Image of Gogo 'calling' of Passenger 1. The experiment starts with system interaction.

All the interaction and conversation are arranged via the messenger before the passenger ride into the car. After the passenger ride in, the machine-generated voice is the only method to communicate with the messenger. Answering the requested question is the only purpose of the voice. If the passenger calls out the command cue wrong, the system cannot answer the request. Even though facilitator generates the announcement, the answer is formed entirely according to the question.

A task order provides the basic tasks during the test, as shown in Figure 26. The participants express their needs aloud while following the task order. The data were recorded, and the extra requests outside the task list were considered critical data. To deliver the system-passenger driving atmosphere, experiment materials were distributed in advance.

Task List		
1	Destination setting	Interaction
2-1	Driving route check	Interaction
2-2	System status briefing	Interaction
3-1	Speed adjustment	Manipulation
3-2	Lane change	Manipulation
4	Resource material review	Personal Task
5	Destination change	Manipulation
6	Communication with system	Interaction
7-1	Arrival	
7-2	Specify stop location	Manipulation
8	Getting off the car	

Figure 26. Task List for Main Test

The testing route is from Seoul National University to Seoul Digital National Industrial Complex 2, which is located in the city center. Following the proposed persona, the route is decided based upon the traffic and the road situation. The experiment time was selected during the daylight when the volume of the traffic is constant. Connection between the driving situation and passenger's request is considered as the key in the experiment. Hence, the 360-dgree was installed for the whole experiment as shown in Figure 27.

Figure 27. Video footage of Main Test. Road condition and the passenger's reaction is recorded.

4.4.4. Result Analysis & Insight

Various visual analysis was utilized for the main test result. The behavioral data of each passenger were graphed visually. The synthetical visual graphing is utilized to find the overlapped timing for the cognitive requests. Through the in-depth interview, their request and cognitive desire were observed and the data were proceeced in the form or 5-point Likert scale.

(1) Behavioral Data

The result of the test shows that the type of information varies based on the type of road (traffic). The request of the four passengers in the main test is visualized as a graph in Figure 28. All the requests were illustrated as a bar. Each passenger is assigned to a specific patterned bar. The length of the bars indicates the tailgating of requests. The solid arrows specifies the request from the passenger, and the dash arrows means the generated response from the AV system. There were four types of road: slow driveway, Freeway, Heavy Traffic, and close to arrival, which indicated as a vertical bar on the left side of the Figure 28. The passenger's requests were recorded during the user test, and a specific behavioral patterns were found.

The request from passenger 1 is indicated as a dotted bar on the Figure 28. The most frequent request from Passenger 1 was the route check. Especially when the car is on the heavy traffic road, Passenger 1 revealed the continuous curious for driving situation. Passenger 2 tend to utilize the system as an information search. Not only for time and driving route, passenger 2 asked for the music search and the singer of the song as well. When the traffic is heavy, constant checking on the remaining time was evident. Passenger 2 explains later in the in-depth interview that it was because the driving seems to take longer than addressed in the beginning of the experiment and she felt uncomfortable to lost track of time.

Passenger 3 showed the least request about the drive. The participants focused on the task list and showed the least curiosity. In the in-depth interview, Passenger 3 explained that the command list contains enough questions to ask about the drive and there were very few needs unless the traffic is especially heavy or the car takes a d-tour to the destination. Similar to other passengers, the route checking and the time tracking followed together. As the traffic gets heavy, there was a cognitive need for estimated remaining time and the following traffic. Passenger 3 asked to control the entertainment unit for music and radio, but soon she rather focusses on the reading materials. In the post-interview, Passenger 3 felt the most struggle to command lane change and speed control because she was not sure when and where to change the lane because she could not guess the upcoming route. If the command list did not contain such commands, she would rather leave speed control and lane changes to the system which has reliable information source.

Passenger 4 is the case who had the time limit. As shown in Figure 28, Passenger 4 asked for the time for the most out of the all participants. Other passengers tend to check just for the remaining time, however, Passenger 3 checked both the current time and the remaining time during the drive. It was not only the traffic area, but also the random time when she was wondering about the time. Moreover, she requested for the specific song and asked a lot of leisure questions to the system such as “what is the closest station?”, “what is your sexuality?”, “Can you read something?” Later in the interview, she responded that she preferred to check the information visually and have a system as a conversation friends in the car.

Based on the observed requests from the main test, all requests were illustrated as a one diagram as illustrated in Figure 28, and a pattern was found: the type of cognitive information are closely related the type of road (traffic). The passengers seek certain types of information based on traffic. In the beginning of the drive, passengers desired to know the driving route, traffic information and estimated driving time. This was also evident in both pilot tests. The high urge for ‘communication’ is observed. Even though the passenger knows the system can handle all of the driving tasks, each participant had different preferences and purposes for driving. They always want to clarify driving status (driving route, estimated time and traffic) and input their preference for driving style (style and route adjustment). High needs for confirmation were noted.

Frequency critically reflected desirable passenger data in the AV situation. There were five significant types of information that the passengers requested during the three tests: route checking, time track, speed, lane change and entertainment. The entertainment category is comprised of music, radio, and questions about surrounding environment.

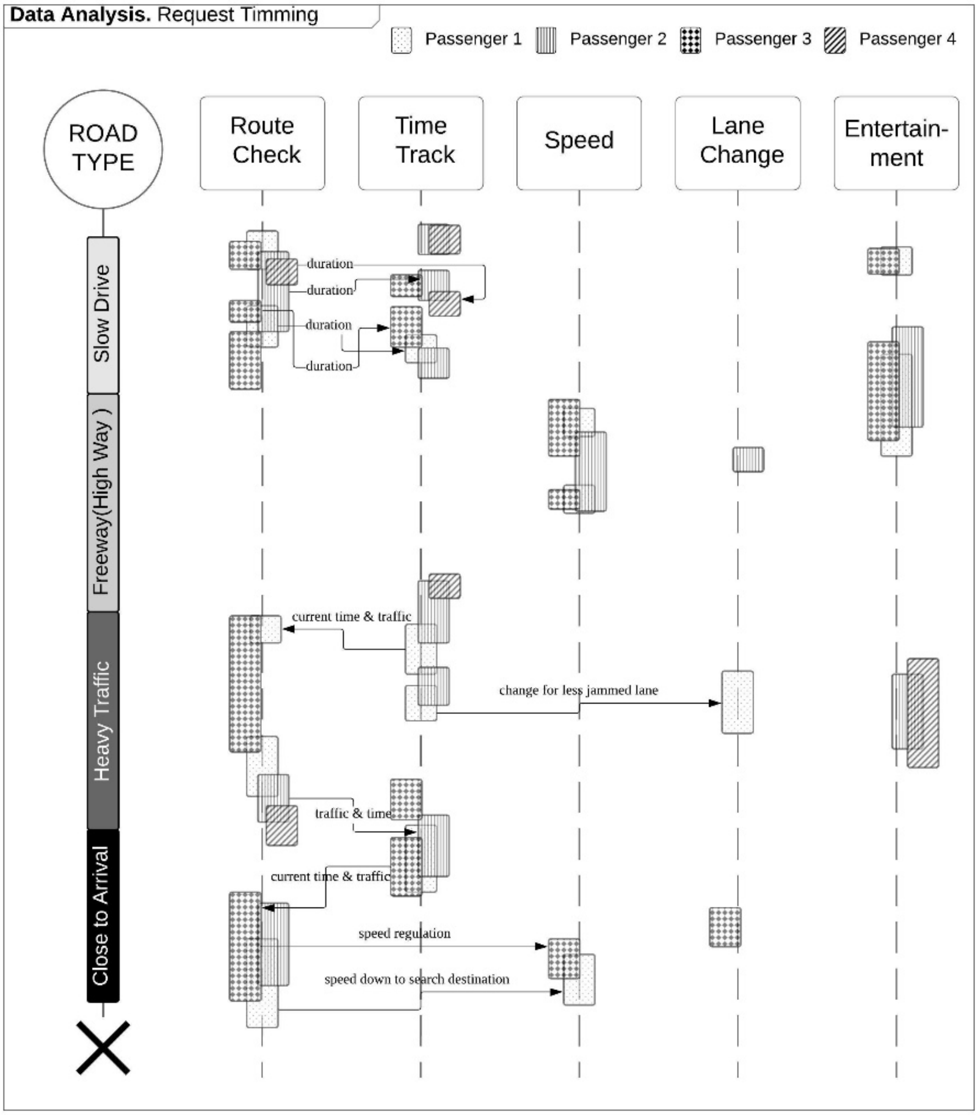


Figure 28. Combined Visual Chart of all Passengers' Cognitive Needs observed in the Main Test

The connection between the timing of the information request and the road situation is observed. The route checking and the time tack mostly requested together and the requests for theses information happen in the beginning of the drive, during the traffic, and at the end of the driving. The most vivid characteristic is that the cognitive needs of route checking and the time checking always requested together. Especially when the participants have a time limit, the constant time checking was observed, and the upcoming route and the traffic are the critical data to estimate the arrival time for the passenger.

It was unanticipated that the cognitive needs for speed control and the lane change revealed very low for all four participants. According to the post-interview, the speed and possibility of lane-change is predictable. In the freeway, the speed was not a critical point, rather the passenger feels more stable and satisfied when the car drives on speed. Very few needs to control the speed is observed. Passenger 3 and Passenger 4 are the only participants to speed down due to safety issue in campus. Other passengers requested to speed up in freeway.

The significance is that while on the highway, which means when the car drives on the speed with smooth traffic, the passenger did not feel the needs of route checking or time concern. Instead, the passenger feels to utilize the driving style, which is the preferences for joy, such as music playing or speed control. The lane changing tend to happen irregularly, however, it can be interpreted that the request was forced by looking at the task sheet given to the participants during the test. In the post-interview, all four passengers answered that they would have not command the lane change if it was not on the task list.

(2) Interview Data

Individual in-depth interviews were conducted following the test. For the pilot test, the questionnaires were primarily about feelings during the driving test and improvements in the laboratory setting. At the beginning of Pilot Test 2, a connection between the passenger's personal situation and behavioral data was identified. For example, Passenger 2 and Passenger 3 in the main test both had time limits. They had events planned after the experiment, and they had to arrive to their destination on time. As a result, they recorded the greatest number of time tracking and route checking. Conversely, Passenger 4 had nothing planned on the test day. Participating in the driving test was an interesting form of entertainment for her. The data shows that Passenger 4 had the lowest frequency of time tracking, instead focusing on the entertainment elements.

The analysis of cognitive needs measured by request frequency for all three user tests revealed the following: 37.0% route checking, 33.3% time tracking, 14.8% entertainment, 9.3% speed, and 5.6% lane change. One insight from the data is that the most critical cognitive feature is 'time.' The three priority elements, route, time and speed, are evident, and these must be utilized as the main design contexts. However, when combined with the qualitative insight gleaned from interviews, the most influential element was 'time.' It is not a simple checking of time, but, rather, a personal situation reflected as time. Having a time limit critically affected the behavior and the cognitive needs of passengers.

The second most critical element is 'route checking.' Statistics show that route checking was the most commonly requested item during the tests. It was evident that the requests for route checking and time tracking always follow each other. The request order varies by passenger preference, but the importance is that the passenger always wondered about both factors together. The data shows that time and route are the two pieces of information passengers desire to know when they are removed from the driver's role. Further, the UI from the perspective of the passenger should be interchangeable based on situational demand.

As shown in Figure 29, the relationship between the traffic and the requested cognitive needs shows a certain pattern. The request for route check and time track always follow along, and the desire for time tracking grows as the traffic gets heavier. There are few request for speed or lane changes. Evidently, on the highway where the car drives at a certain speed, there is no cognitive request about the driving status, rather the passenger tend to focus on the entertainment features.

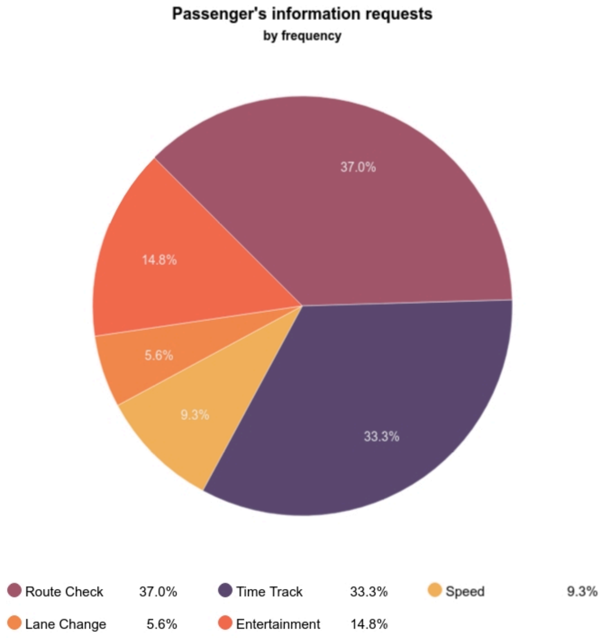


Figure 29.Passenger's cognitive needs measured by the frequency of all tests.

The passenger's cognitive needs that were observed throughout the all user tests includes Pilot Test 1, Pilot Test 2 and the Main Test are visualized as a pie chart as shown in Figure 31. The percentage is depicted by the frequency of the request. For example, one request of the route check calculated as 1 data-wize. The chart depicts that the most of the cognitive need concentrates on two needs: path check and time track. These two data take the majority of the informative needs among passengers. It can be translated that route check and the time track is the main informative context that is needed in perspective of the passenger.

Chapter 5. UI Concept Development

5.1. UI Design Method

In-vehicle UI, especially the driver aid system design, should enable drivers to minimize their cognitive burden and better comprehension for a stable driving environment[29].The navigation system is widely utilized in vehicles, and its capability has grown. Navigation is the main source that the drivers get the information from but at the same time the most disruptive element in the vehicle. It should not disrupt the driver's cognition or any other information source. Lee et al. proposed a set of navigational interface design guidelines considering the understanding of human factors, cognitive science, human-computer interaction, and information design. The guidelines focus on visual information and their presentative rules for better comprehension.

[29] Joon-Hwan, Lee, and Jun Soo-Jin. "Design Guidelines and Recommendations for In-Vehicle Navigation Systems." *Archives of Design Research* 23.3 (2010): 309-327.

Predictability, Familiarity, and consistency are the three design principles are presented in the study for high usability and low confusion of finding information. Predictability means the system needs to give out predictable alert and warnings to minimize the shock of the driver. In other words, the system should not give out or abuse the warning sound at random point. Familiarity means utilization of the similar symbols that the drivers often acknowledge such as the road symbols the national highway system. It helps the driver to adopt the information quicker and easier. Consistency is the key design principle that could significantly reduce the perceptual load for the driver. The consistency of visual element, property, terminology over the entire design provides a stable reading of the information. Also, keeping consistent intervals of notification is important. Therefore, the driver is able to construct a mindset to react to the system. Most of all, affordability is the fundamental consistency principle rule. The interface needs to display only the appropriate amount of information, so the driver can comprehend the provided information when looking at the display.

Lee et al. also recommended specific design guidelines for each composition elements. The guidelines are gathered for visual comprehension. There are four categories: Legibility, Understandability, color scheme, and contrast, and abstraction. There are specific guidelines on each category as follows.

Table 14. Recommendation of Design guidelines of each categories

Categories	Guidelines
Legibility	**Character size** **Guideline1:** For displays mounted on top of or near the top of the center console, character height should be approximately 0.26 inches high (6.4 mm) **Guideline2:** the smallest character size tested in the driving conditions were about 5 mm (Boreczky et

	al.) **Guideline3:** increasing the character size to 9 mm, reading time of the character was decreased by 15 to 20 percent, and increasing the size further to 12 mm to 16 mm resulted in further decreased reading time, although the gains were diminishing (Green et al., 1993) **<u>Typeface</u>** **Guideline:** Use a plain typeface designed for screen to maximize legibility.
Understandability (Readability)	**Guideline 1:** Use mixed case instead of all capital letters. **Guideline 2:** Use consistent rules when creating abbreviations. **Guideline 3:** Use common abbreviations.
Color Scheme and Contrast	**Guideline 1:** Use high contrast. **Guideline 2:** Color scheme should consider ambient lighting condition. **Guideline 3:** Use color consistently. (e.g., same landmark with same color coding) **Guideline 4:** Use color to draw attention, communicate organization, and indicate status. **Guideline 5:** Limit color-coding to eight colors (four or less is preferable) *note: these specific 8 colors are not necessarily a recommended color set.
Abstraction	**Guideline 1:** Minimize the amount of information to reduce search time. **Guideline 2:** When abstracting map information, apply generalization rules consistently.

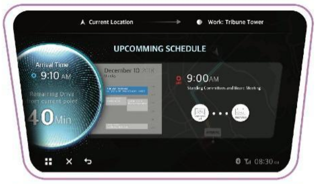
The purpose of the guidelines above is to reduce cognitive burden and derive a congruent environment to provide information. It is a good reference with a fundamental proof when choosing design elements.

5.2. Design Proposal

Through the experiments, a strong need for time is observed. The base desire for such a situation is because the passenger focuses more on absolute value like time and the variables that are influenced by the traffic condition. It constructs the variable interface that supports such desire of the passenger through sketching. The design follows the three principles of predictability, familiarity, and consistency for high usability with little confusion.

Key UI features are shown in Figure 30. The main UI component for the proposing UI is the modal window on the left. The window is the most highlighted visually and provides the two critical information observed from the previous user tests: arrival time and driving duration. For the both user scenarios of time-less and time-full, the informational window is placed on the left side of the cluster UI. For time-less scenario, the modal window displays time tracker as depicted in Figure 30-A. The second key feature is the proposal of diverse driving purpose as shown in Figure 30-B. The feature is specialized for the time-full user scenario, and it proposes the future mobility culture of entertaining space. When the destination is not set, the AV system suggest three options of Favorite places, recommended places, and anywhere. The feature highlights the personalization of the vehicle accordance to the passenger's driving purpose. The last key feature is the informational window and parking guide as illustrated in Figure 30-C. It is the visual communication utilizing network system of autonomous driving system. With this feature, it highlights the space to space connectivity without in-between time of setting destination or looking for a parking space.

The unique difference from the existing study is the speedometer, the gear premotor and fuel gauge are vanished on the proposing cluster UI. The result of the user tests and in-depth interviews shows that the mechanical data, which the AV system is capable of, was not a critical information in the perspective of the passenger. The passenger revealed their curiosity on the situation-related information more judiciously than on the data that are set as a regulation, which the AV system observes strictly.



A. TIME TRACK & SCHEDULE OVERVIEW
Highlighted UI for arrival time and remaining driving time. Personalize system as a schedule manager, and alert UI for upcoming event.

B. DRIVING PURPOSE OPTION
Diversify driving purpose of three choices.
Favorite places: a list of places that the passenger visited most often
Recommended places: Suggested places around the passenger's location
Anywhere: Automatically set driveway based on the user, traffic and location data

C. TOUR GUIDE
Informational window for surroundings with picture and guide information of the suggested place.

D. PARKING OPTIONS
Two parking: parking lot and drive-around mode.

Figure 30. Key UI design components

Based on the key UI features and the user tests result, two user scenarios are proposed.

5.3. User Scenarios

Based on the key UI features and the user tests result, two user scenarios are proposed by time variable. The result shows that the most critical influence was the time limit. The UI in the perspective of Passenger should interchangeable on their situational demand. Therefore, the scenario of the UI Working flow is divided by the time variable as Time-less and Time-full user scenario.

When there is a time limit, the UI should be designed with a focus on time consumption. When there is no time limit, the system should acknowledge the trip as leisure driving and set the driving route based on this recommendation. The UI framework is transformed into a location recommender. Based on the results, the UI Autonomous concept is developed. The design follows the three principles of predictability, familiarity, and consistency for high usability with little confusion.

5.3.1 Scenario 1. Time-less: Late for a morning meeting

Scenario 1 is designed for the time-less situation, where the purpose of driving is transportation between two locations and there is a specific event at which the passenger needs to arrive as shown in Figure 31. Scenario 1 is when passengers use the car as transportation between one place and another according to their schedule.

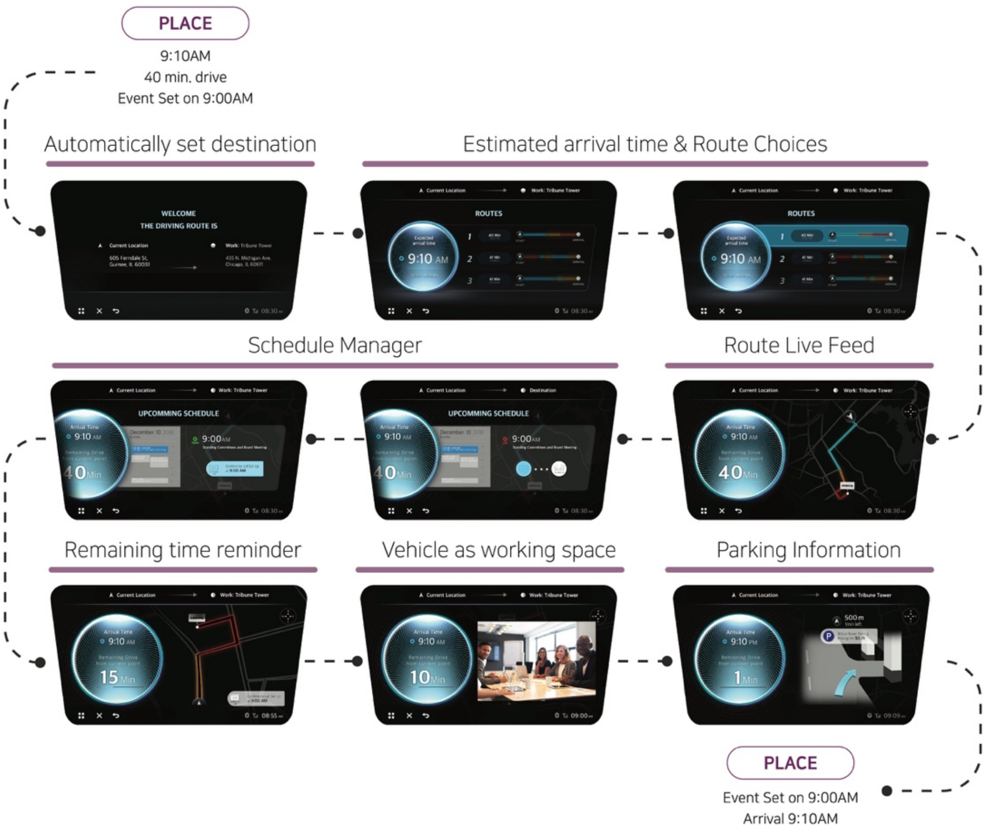


Figure 31. Time-less Scenario UI Workflow

The specific UI for Time-less scenario is as follows:

(1) Driving route and arrival time

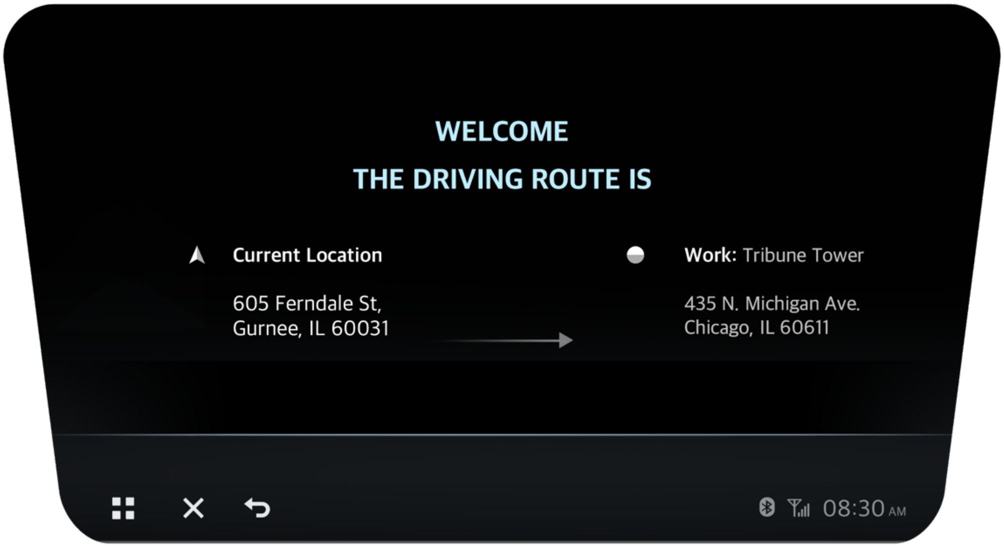


Figure 32. destination display

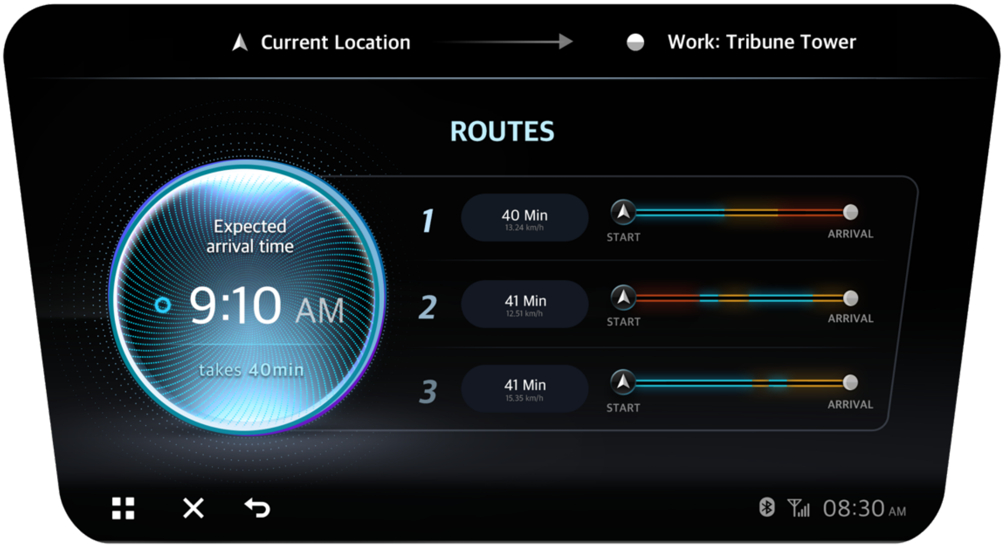


Figure 33. The estimated arrival time displace and Route suggestion by the fastest route.

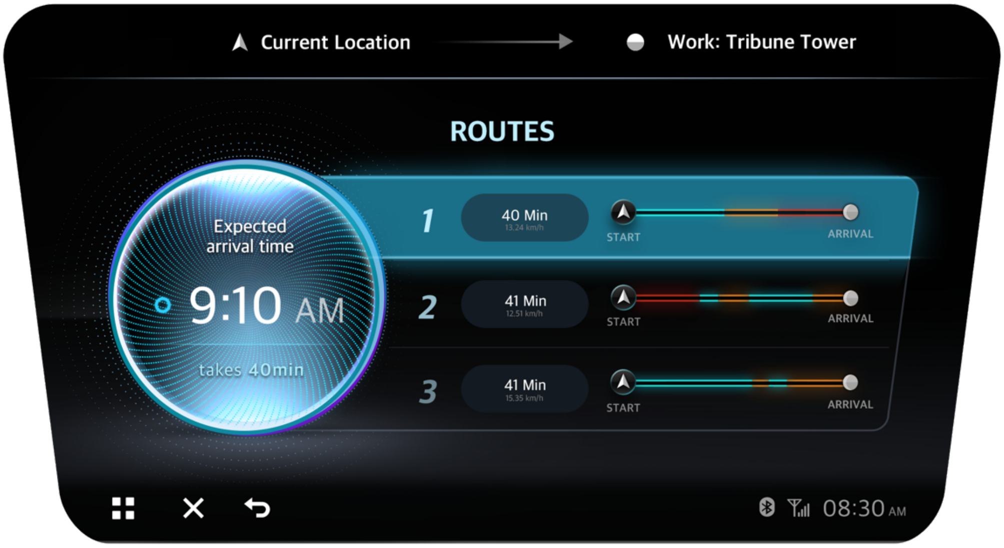


Figure 34. Passenger can select the route.

(2) While driving

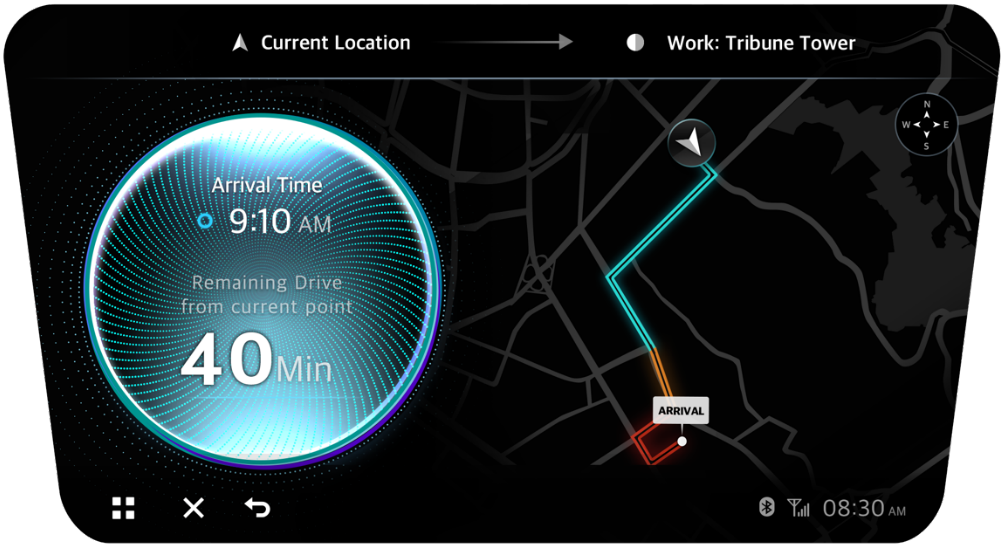


Figure 35. driving route display with the traffic notification.

(3) Personal Schedule alarm and complementary suggestion

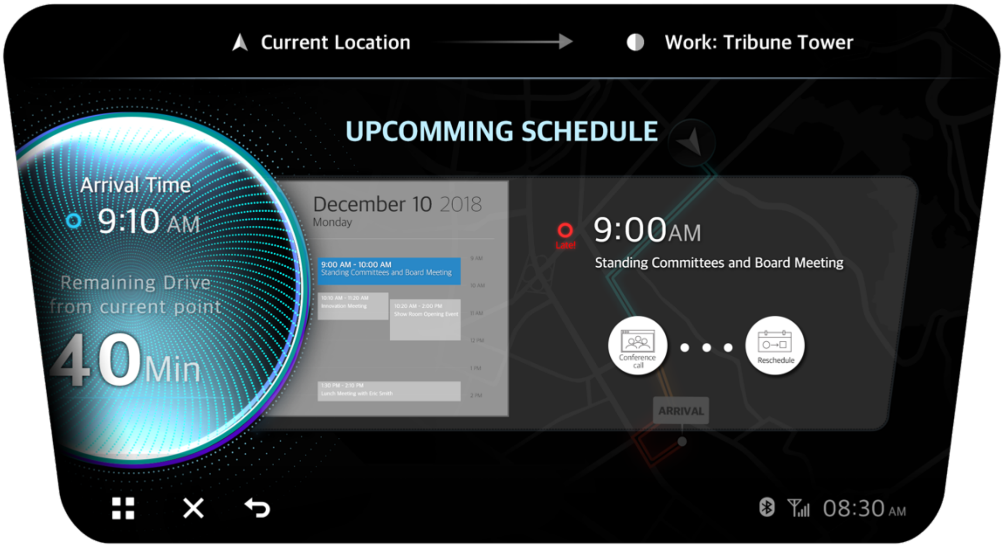


Figure 36. personal schedule alarm.

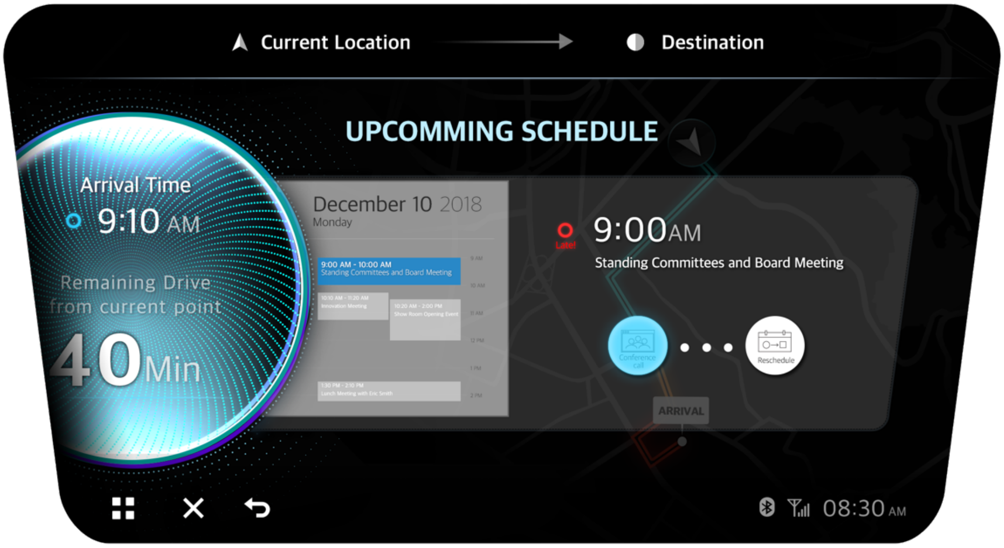


Figure 37. Supplementary choice suggestion.

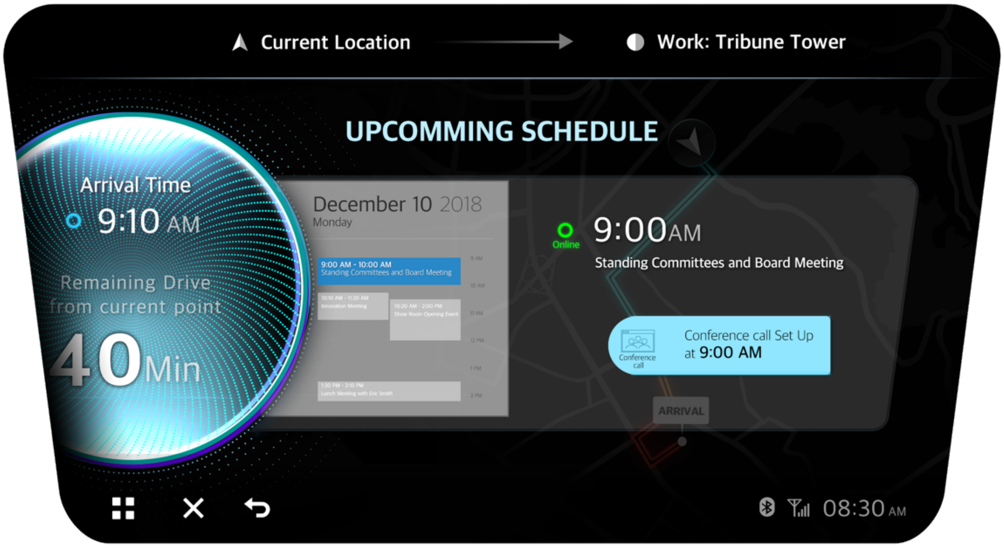


Figure 38. passenger's choice

(4) Notification of the conference call

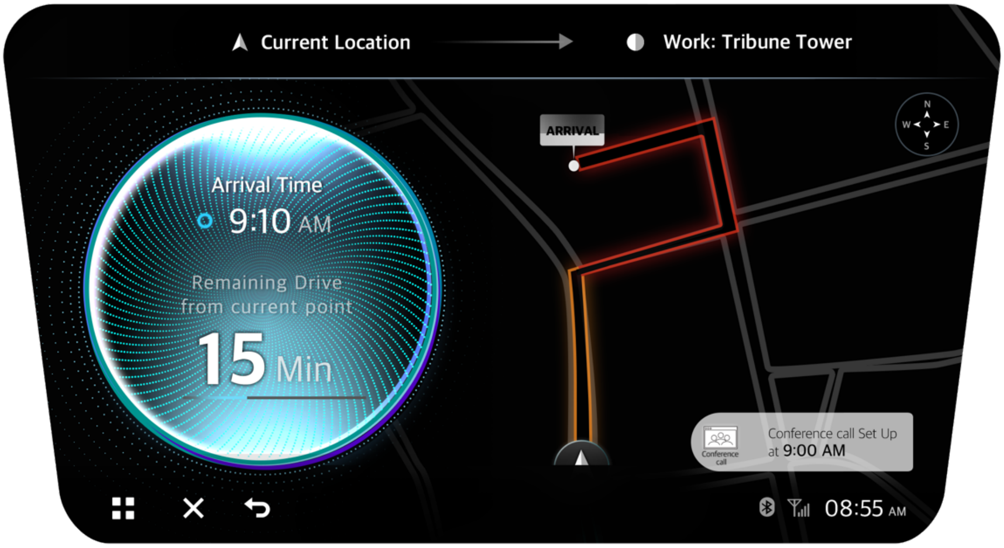


Figure 39. conference call notification on the route display.

Figure 40. conference calling as a part of the UI

(5) Parking scenario

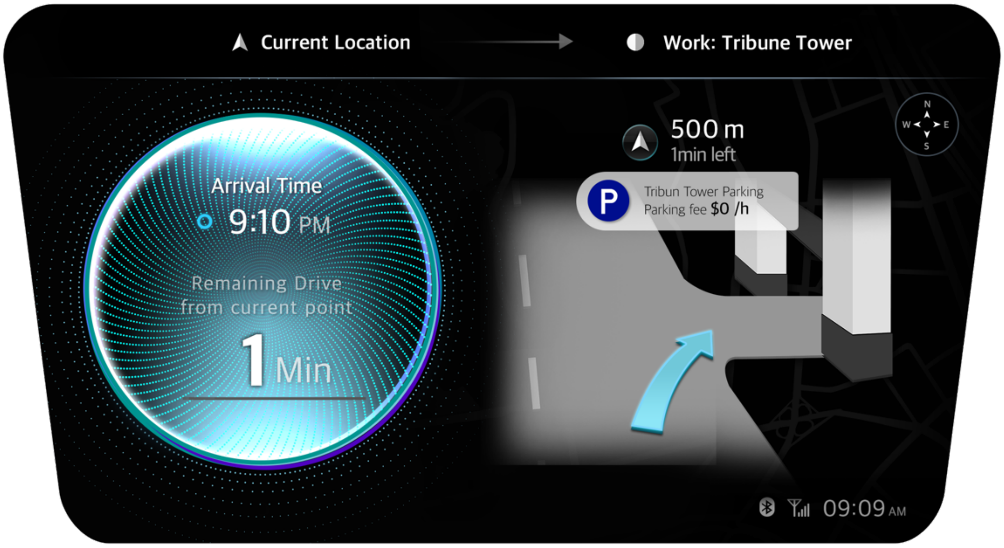


Figure 41. parking information

5.3.2 Scenario 2.Time-full: Leisure driving on weekends

Scenario 2 is designed for the time-full situation where the purpose of mobility is to explore locations. The car acts as a device to suggest locations and connect the passenger's interest to a new location. In scenario 2, the car can offer suggestions about places for passengers to spend their time enjoying rich experiences. Figure 42 shows the UI flow of Scenario 2.

Figure 42. Time-full Scenario UI workflow

The proposed UI takes charge of sole communication channel between the passenger and the driving system, which originally managed by multiple features as cluster screen, center fascia, and navigation. The most distinguished feature from the existing research of the cluster UI is that driving speed and traffic regulation features are no longer considered as the critical elements. Those elements are processed through the AV system and they do not affect the passenger's situation awareness due to the collected empirical data.

The specific UI for Time-full scenario is as follows:

(1) Driving type choice

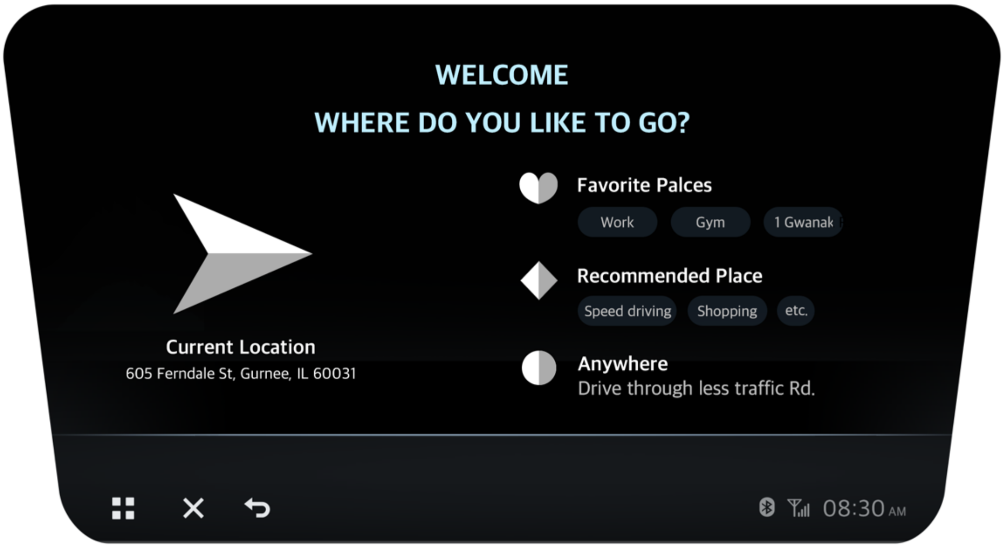


Figure 43. driving type choices. Favorite place saves the mostly visited place information, and recommended place has a category of place for the suggestion.

(2) Driving route suggestion

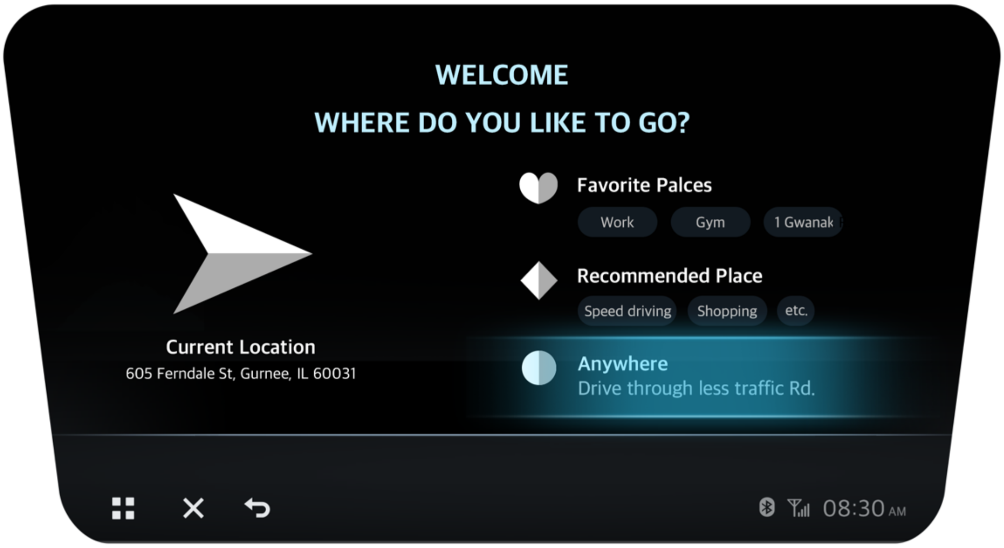


Figure 44. Driving type selection style.

(3) Place to visit information

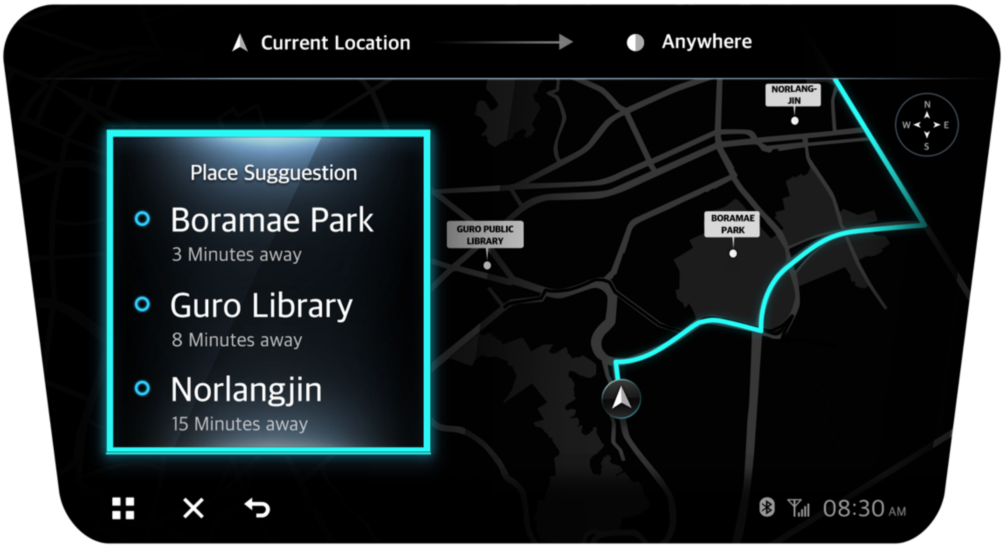


Figure 45. driving route information. The driving route is automatically suggested by the system.

(4) Destination setting

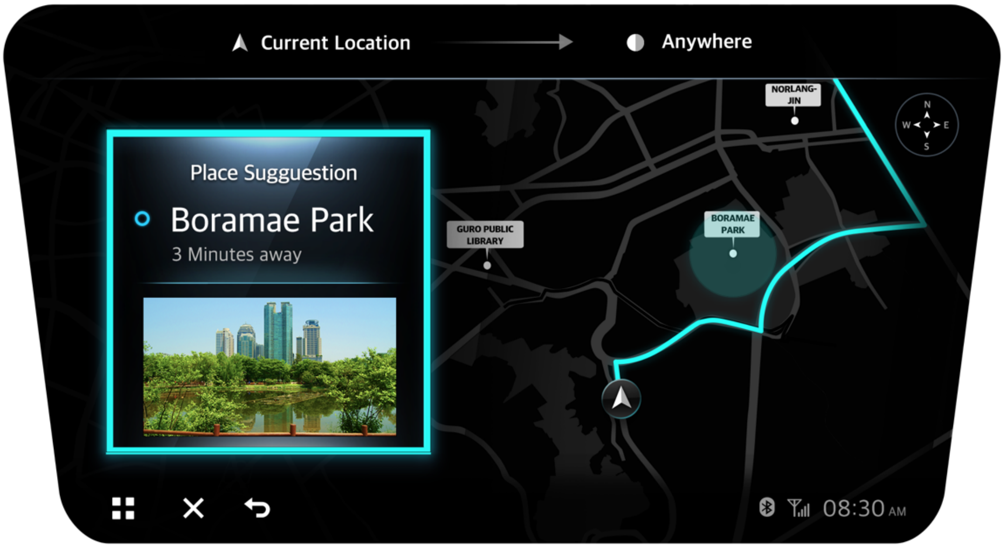


Figure 46. Location recommendation on the map. The system suggests places to stop and provide information about each place

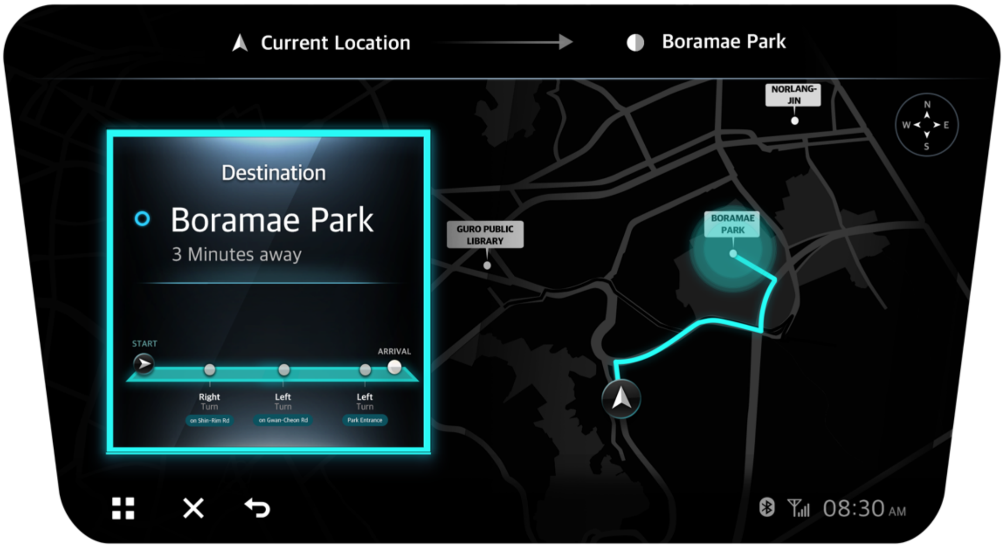


Figure 47. One of the recommendation selections and the extra information provided on the left.

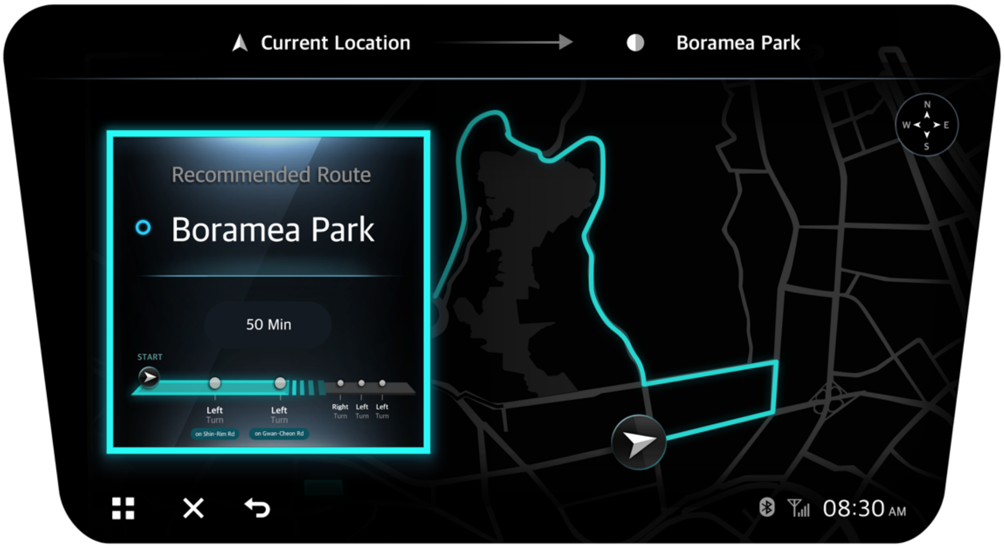


Figure 48. Change destination by one more click on the recommendation.

(5) parking choice

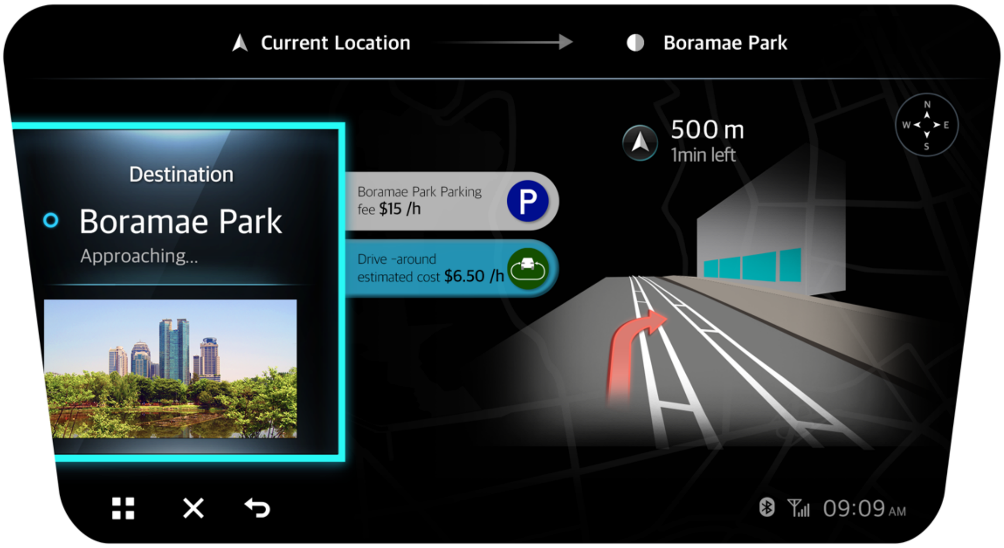


Figure 49. parking choice with the stopping type and the cost.

Chapter 6. Usability Test

6.1. Usability Test Guide

The proposed UI is designed to support passengers in the new mobility culture. The usability Test is held to test a product's effectiveness, efficiency, and satisfaction in a specific context of use[30].The usability test could help in every stage of product development. It helps to get aim view on the product and observe errors in usage. There are four different usability test: exploratory, assessment, evaluation, and comparison test[31]. Each type has a different purpose and the time to perform as shown in Table 15.

Table 15. Types of Usability Test and usage timing classified by Rubin et al.

Test Type	When	Objective	Methodology
Exploratory or Formative Test	Early design phase	To examine the effectiveness of the design concepts	User Task walkthrough with a basic layout, basic questionnaires about formation or confusing elements
Assessment or summative Test	Early to midway into the product development phase	To determine how effectively the concept has been implemented	Information-gathering or evidence-gathering test of the participant's behavior. The behavior and reaction, sometimes time can be measured.
Validation or verification Test	Late in the development phase,	To measure usability of a product against established	Similar to the Assessment Test. measuring user performance against a standard

[30] Dumas, Joseph S., and Janice Redish. *A Practical Guide to Usability Testing*. Intellect, 1999.
[31] Rubin, Jeff, and Dana Chisnell. *Handbook of Usability Testing, Second Edition: How to Plan, Design, and Conduct Effective Tests*. Second ed., Wiley Publishing, Inc., 2008.

	Prototyping phase/ Demo-use phase	benchmark, or to confirm the error remedy	
Comparison Test	Often early design phase, but may be performed at any time	To compare the potential between two or more design, or to measure the effectiveness of a single element	Performing same task on different design and compare the superior design/element. The finding can be used as an insight to improve the developing design.

Assessment Test and Validation Test are often used at the end of the product development phase. Two types of usability tests utilize similar methodologies. The difference is when to perform. Assessment Test is help at the end of the development phase, often right before the product release. It is the test where the designer/developer make sure the product is successfully implemented its design goal and functionally work. On the other hand, Validation or Verification Test is helping after the product is released or when the product is already in service to as a demo version or prototype. It is the test with long-term and constant adjustment action targeting a large group of participants[32]. For the Proposed UI, it is the prototype of the situation-supported interface design, and the Assessment Test is an appropriate Usability Test to measure its effectiveness on passenger's cognitive information adoption and satisfaction of users.

The process of the usability test is (1) Test planning, (2) Laboratory setting (environment setting, Recruiting, Test material preparation) (3) Test conduct and debriefing, (4) Post-Test discussion and questionnaire, and (5) result Analysis.

[32] Rubin, Jeff, and Dana Chisnell. *Handbook of Usability Testing, Second Edition: How to Plan, Design, and Conduct Effective Tests*. Second ed., Wiley Publishing, Inc., 2008.

6.2. Assessment Usability Test

6.2.1 Test planning

The usability test is held to test a product's effectiveness, efficiency and satisfaction in a specific public use context. 10 Participants were recruited from previous all three user tests. This is because they understand the passenger-only driving environments and they can compare the driving experience in the plain setting with the one in the UI design. The purpose of the test is to objectively measure the advancement of the proposed UI based on four factors: effectiveness, efficiency, satisfaction and ease of learning.

The design goal of the UI is to support passenger's cognitive needs in the future mobility, and the user test is planned to determine whether the UI acquires the design goal and to observe the strength/weakness for the future development. The structure of the usability test is as described in Table 16.

Table 16. Assessment Usability Test plan

Purpose	Determining the effectiveness, efficiency, satisfaction, and understandability of the proposed UI
Total participants	5
Test duration /person	Scenario 1(Time-less): 5minutes Scenario 2(Time-full): 10minutes
Materials	1 Monitor, 1 Tablet PC, hard copy of the Questionnaires, 1 pen, hard copy of Persona, alarm clock
Method	Prototyping of a product, videotaping, talk-aloud, post-interview

The participants were recruited from the participants of the previous user tests. It is because they understand the passenger-only driving environments and they could compare the driving experience in the plain setting and the one with the UI design.

The purpose of the test is to objectively measure the advancement of the proposed UI in four factors:

A. **Effectiveness:** Does the UI provide provides appropriate information according to the driving situation for the passenger?

B. **Efficiency:** How long does it take for the passenger to conduct the desired information through the proposed UI?

C. **Satisfaction:** Does the UI allows the passenger to utilize it according to their needs? Does the UI interactive to the passenger's request?

D. **Easy to learn:** Does the passenger is able to intuitively figure out how to use the UI without question?

All participants will experience two types of scenarios: Scenario 1: Time-less and Scenario 2: Time-full. For scenario 1, an alarm clock will be set for 5 minutes to give the time limit to the passenger. There are four different driving situations: speed restricted road, Highway, Heavy Traffic and close to arrival. The video footage of each driving situation will be played for 1 minute. While the passenger looks at the video footage, the participants talk-aloud for the cognitive needs as they experienced in the previous user tests. A packet of reading material will be given to the passenger. The participants will experience the time pressure to complete the tasks within the time and to check the UI.

For scenario 2, there is no time limit and the only low-volume traffic roads will be provided. The participants freely manipulate the UI screens. There will be no reading materials and the participants need to look at the video footage. The location suggestions will be given through the UI screen, however, they can talk-aloud any requests if they want extra information such as a gas station or a drive-through restaurant.

6.2.2 Laboratory setting

As addressed in Rubin et al.'s book, the formation of the test environment described in Figure 50. The usability test often held in a private room such as an office or a classroom with a monitor. It is important to record the reaction of the participants; therefore, the webcam is installed on the monitor. The designed product is displayed on the monitor and the participants sit in front of the screen. The participant talk-aloud of their thoughts while the test is running. The moderator seats in the back and observes the reaction of the participants. Taking notes of the participant's reaction and record the extra questions regarding their thoughts becomes the crucial observing point for the post-interview.

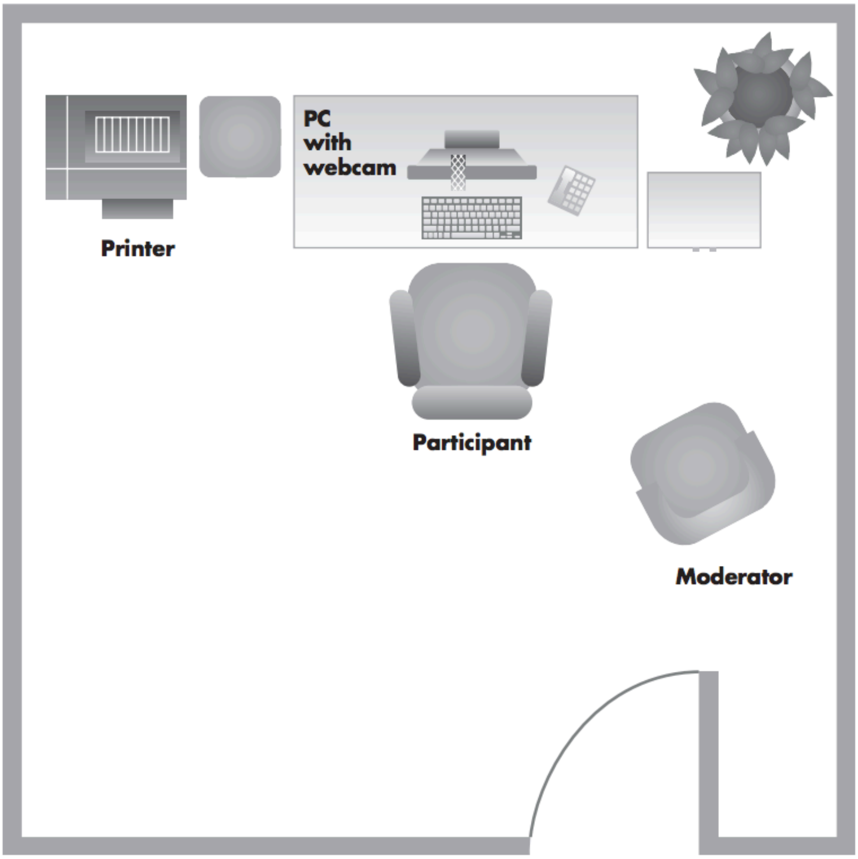


Figure 50. Test monitor and participants exploring the design. (image retrieved from Handbook of Usability Testing, Second Edition: How to Plan, Design, and Conduct Effective Tests by Rubin et al., 2008)

The usability test was held in a laboratory setting. Two screens were provided to participants; one screen played video footage of the road, and the other screen displayed the proposed UI. The relationship between traffic and driving status is critical, because passengers sought different types of cognitive information in relation to the road situation. Therefore, two screens were provided to the participants as shown in Figure 51.

The two proposed usage scenarios were given to the participants as an introduction of each set of UIs, the participants measure 6 aspects in relation to the given road situation.

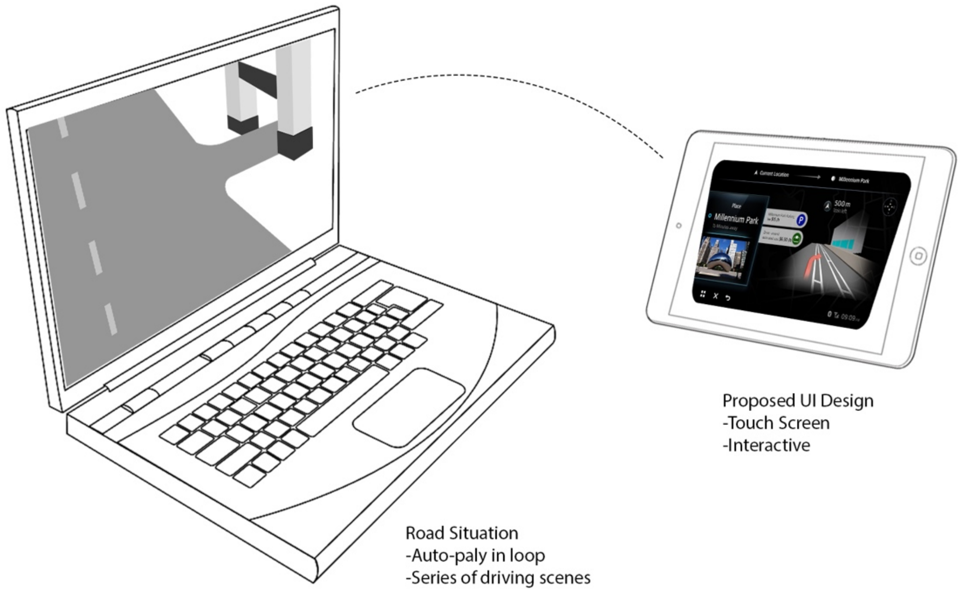


Figure 51. Usability Test Laboratory Setting with Road Situation Screen and Proposed UI design screen.

The video footage of the road is retrieved from the video record from the user tests. The four different driving road type for scenario 1 is selected from the area where the passengers reveal the most cognitive needs. Video footages of each road type look as shown in Figure 52 through Figure 55.

Figure 52. (C1)Video footage of the Speed Restricted Road

Figure 53. (H2)Video footage of the Highway

Figure 54. (U3)Video footage of the road with High Traffic volume

Figure 55. (A4)Video footage of the approaching to the destination

The interaction between each scene and the flow are the crucial aspect. Hence, the prototype is reproduced as an interactive interface with touchable feedback with the aid of Adobe XD. The reverse function is provided to going in case of the passenger wants to go back to the previous screen.

6.2.3 Test conduct and debriefing

Cognitive Needs	Scenario		road type	Task	UI Scene	Start time	stop time	Begin Dialogue	End Dialogue
Pssg 1		Title					Usability		
destination setting	1	Positive	-	destination setting	Figure 34	0:05	0:10	Hey Gogo, Let's go to Boramae park.	
	1		-	destination check	Figure 34	0:10	0:12	okay.. let's go	
	1	Negative	C1	route select	Figure 35	0:13	0:30	okay i need to select the driving route..	... the fastest one seems like the only choice. I will select the first one. I wonder which road it is. it does not say.. only the traffic volume is given.
	1		C1	Route check	Figure 37	0:31	0:37	the driving route.. so it goes like this.	.. The traffic is not bad. alright.
	1	Positive	C1	Schedule Check	Figure 38	0:47	1:05	Late for schedule!	... is there no faster way? i like to search for it.. I like to search the route one more time just in case.
	1		H2	Supplement choice	Figure 39	1:09	1:18	well, I will select the conference call.	...if it is replaceable with the call, I would rather finish the meeing in the car though.
	1		H2	Supplement choice	Figure 40	1:19	1:20	confirm conference call at 9. okay.	
	1	Positive	U3	Time Check	Figure 41	2:00	2:06	move to another road. It drives well.	...5 minites before the conference call.
	1	Negative	U3	Supplement choice-task	Figure 42	2:30	2:45	conference call screen pop-up okay. hello!	.. I wish I know how I look on the screen too. and minimize the video screen as well. too akward..
	1	Positive	A4	Information check	Figure 43	3:00	3:06	arrived! it is good that it let me now the parking fee as well.	
	2	Negative	-	Information check	Figure 44	0:00	0:13	Hey gogo, Let's drive	...is this an option button? can I click them? wich the options would look more like a button.
	2		-	destination setting	Figure 45	0:20	0:23	Hey gogo, take me to anywhere!	
	2	Positive	C1	Route check	Figure 46	0:25	0:35	parkside drive? alright. no traffic, I like it!	...Still, I want to know what kind of roads that it would gonna drive. no idea where it would go from this view.
	2	Positive	H2	Information check	Figure 47	1:00	1:09	Okay. there are places around here.	...Boramae park?! what is in that park? I have no idea.. I have never been.
	2	Positive	H2	Information check	Figure 48	1:13	1:30	oh! it gives the specific information?	...I like this feature, but I wish there is more information not just a picture like related history or something.
	2	Positive	H2	Information check	Figure 49	1:31	1:43	If I click it, the route is changed.	...oh this one gives you the specific route and the road names! this one is way better than the previous one.
	2	Negative	A4	Information check	Figure 50	2:00	2:10	arrival to the road side.	... then how what would I do? do I get off? I wish the car let me know when to get off.

Figure 56. Conducted Usability Test dialogue raw data. The example data of Passenger 1.

The dialogue and the time are recorded for the five participants. Each participants were vocally instructed how to follow the monitor and the Cluster screen usage before the usability test. There was no inter-communication with the moderator, however, the participants were allowed to freely express their feeling or thoughts during the test. Every reaction is recorded by camera and note taking.

6.3. result Analysis

Satisfaction and improvements were rated based on a 5-point Likert scale for each question, and the results are shown as a graph in Figure 11. Satisfaction related to time and route features is dramatically resolved. Even though there are still enhancements for future study, the overall cognitive needs of the passenger are resolved, and the data itself provides an objective understanding from the passenger's perspective.

#	Task name	Min.	Max.	Mean
1	System Communication - The system was straightforward to use without a special instruction.	1	3	1.8
		4	5	4.7
2	Estimated Driving Time - I was able to track on estimated driving time.	1	2	1.3
		5	5	5
3	Current time Recognition - I was able to track on current time.	1	4	2
		4	5	4.9
4	Route Recognition - I was able to check on route while driving.	1	2	1.2
		4	5	4.9
5	Traffic Information Recognition - The UI provided enough information for the curiosity on driving	1	2	1.4
		3	5	4
6	Personal Preference - The UI provided enough choice as a subjective passenger.	1	3	2.1
		3	5	3.8

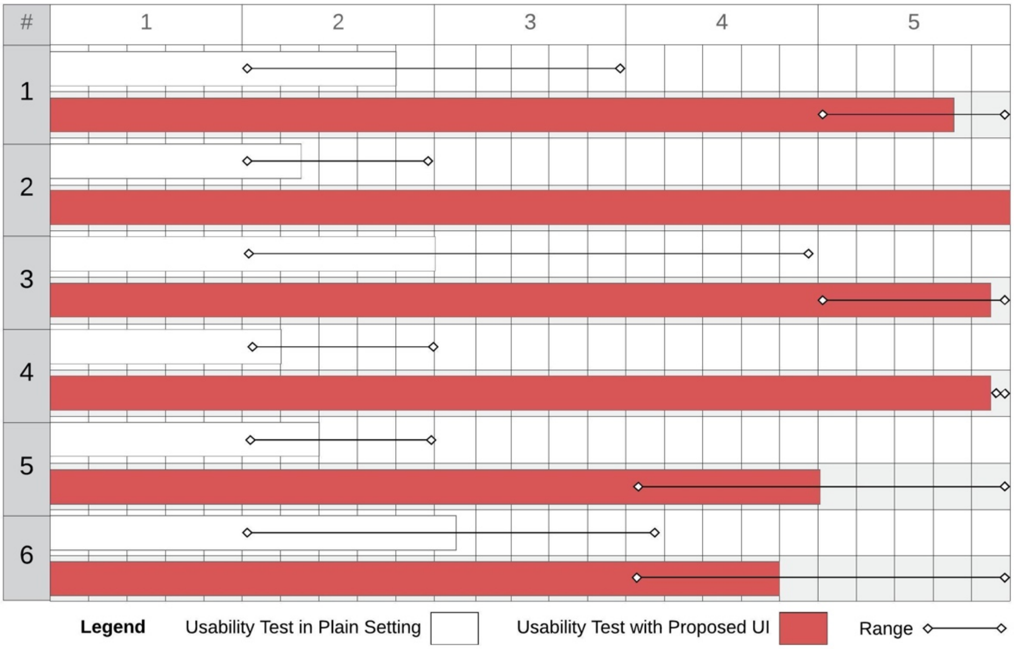


Figure 57. Usability Test Result in Comparison of Plain Setting and proposed UI

Chapter 7. Conclusion

This study collected a set of empirical data on passenger's cognitive needs and conducted an analysis of required features for passenger-centered user interface in AV. The procedure is based on the premise that the automation technology is fully operative and trusted.

The desired cognitive needs of the passenger were observed in detail. The three controlled user tests revealed a gap between participants' requests before the experiment and their actual cognitive needs in real situations as passengers. With the visualizing reference for in-vehicle UI, a cluster design supporting the passenger's viewpoint is proposed. The proposed UI is an example of the development in the direction of supporting the passenger's cognitive needs. Based on the research and the test analysis, the cognitive framework of the 'passenger' can be completed as shown in Figure 58.

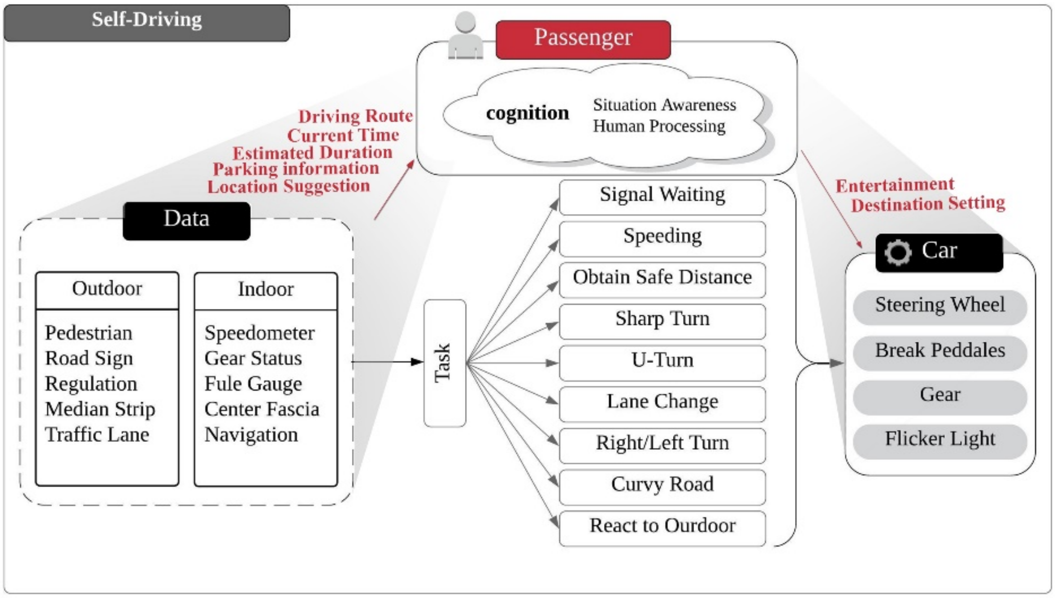


Figure 58. Completed Version of Cognitive Framework of the 'Passenger' in Autonomous Driving

The cognitive model of the passenger is completed as a final progression of the study. In comparison with the cognitive framework of a driver, all of the data is directly provided to the car. All of the driving tasks are managed by the system, and the passenger's role is to manage the situation and request desired information from the system.

This study contributes to ongoing progress in the development of the cluster UI for this new mobility form. Autonomous technology has not only changed the cultural aspect of driving, but also the relationship between the 'passenger' and the vehicle, due to the extended ability of the operating system. The car perceives the road data and is capable of situational judgment and the driving task. In this case, passengers can reflect their preferences based on their situation, such as going on a trip, commuting, or heading to a nearby destination. In automation technology, humans and the Autonomous system share the responsibility of data processing. Based on the premise that the Autonomous car is capable of all driving tasks, human operators take on the role of 'passengers' because they do not 'drive' a Autonomous vehicle.

Appendix 1

탑승자 태스크 시트

실험 중 참여자가 실행할 행동 순서 및 task

인지정보 관찰을 위해 제공되는 기본적인 Task 시트입니다. 순서에 따라 수행하게 되며,

리스트 외에 원하는 Task 는 자유롭게 추가 가능합니다.

(ex. 버스 추월, short-cut 으로 루트 변경, 골목길에 잠시 정차 등)

1-1	대학원 수업 후 도심으로 목적지 설정
1-2	**정보확인**: 이동 루트 확인
2-1	**컨트롤**: 차량 출발
2-2	차량 출발 인지
2-2	**정보확인**: 교통정보 확인
3-1	이동 중 글읽기
3-2	**정보확인**: 위치확인
3-3	**컨트롤**: 선호에 따라 차선 바꾸기
3-4	**컨트롤**: 차량 속도 조절(up & down)
5	목적지 도착이 가까워지면 주변 정리 시작
6	**컨트롤**: 정차할 곳 입력
7	목적지 도착 후 하차

Input Command 에 다른 시스템 리액션

정보확인: 인풋 확인음#1 와 함께

컨트롤: 인풋 확인음#2 와 함께 탑승자 input 에 따른 주행 변화

Appendix 2

Input Command

Operator 의 주행 상태를 변경할 수 있는 Command 언어

Operator 는 운전을 수행하는 인공지능시스템과 같은 역할을 합니다. 최대한 실제 자율주행 차량과 흡사한 상황을 위해 Operator 와 실시간 소통은 제한됩니다. 그러나 Command 언어를 사용하여 사용자의 preference 를 주행에 반영할 수 있습니다. Command 언어는 오퍼레이팅 시스템을 부르는 것처럼 operator 입력의 시작을 알리는 **calling 명령 후 원하는 주행 변화를 입력하는 방식으로 진행**합니다.

예) **calling 명령+주행 변경 값**

Commander change the lane to the right. 커맨더, 오른쪽 차선으로 변경해줘요.

명령 언어 리스트는 다음과 같습니다.
해당 리스트는 기본적인 명령어로 구성되어 있으며, **자유롭게 변형 또는 추가 가능**합니다.

calling/ 입력 값 시작	**Hey,Gogo/ 헤이, 고고**
목적지 입력	○○○로 가자./ 목적지를 ○○○로 세팅해줘요.
주행 시작	출발
루트 확인	이동 루트 말해줘요.
도로정보 확인	현재 도로 교통정보 말해줘요.
차선변경	왼쪽 차선/오른쪽차선으로 변경해줘요.
속도 조절	속도를 조금 높여줘요. 속도를 조금 낮춰줘요. 속도를 5km 높여줘요./낮춰줘요.

주행 멈춤	잠시 차를 세워줘요. 차를 세워줘요.
목적지 변경	잠시 ###에 들려요. 목적지를 ###로 변경해줘요.
명령 값 취소	방금 명령 취소해줘요.

Appendix 3

[Main Test_ Experiment Handouts]

탑승자 관점에서 주행 정보 타입 관찰 실험
(가상 자율주행 적용 방안 실험)

실험 목적 및 과정 안내

안녕하세요. 탑승자 관점의 필요인지정보 실험에 참가해주신 것에 감사드립니다. 본 실험은 시스템이 운전 태스크를 담당하는 주행 환경에서 운전자의 관점이 아닌 탑승자의 관점에서 상황인지를 위해 필요로하는 정보 타입을 관찰하는데에 목적이 있습니다.

본 실험에서는 실제 차량을 이용한 재현된 자율주행 환경에서 편도 30분, 왕복 1시간 동안 진행됩니다. 주행루트는 서울대에서 출발하여 도심으로 주행하며, 서울대에서 도심으로 출발하는 동안에는 인지정보가 전혀 제공되지 않은 상태에서 주어진 Task list와 Command를 활용하여 주행을 경험하게 됩니다. 반대로 목적지에 도착 후 서울대학교로 돌아오는 길에서는 3가지의 UI mock-up 디자인을 통해 필요 인지정보를 주행에 반영하는 실험을 하게될 것입니다.

탑승자는 조수석에 탑승하게 되며, 운전석과 탑승석 사이에는 칸막이가 설치되어 대시보드, 네비게이션, 센터페시아 등 운전관련 정보가 가려집니다. 탑승자는 주행에 대한 아무런 정보가 전달되지 않는 상황에서, 오직 주행상황에 탑승자로써 놓여지게 됩니다.

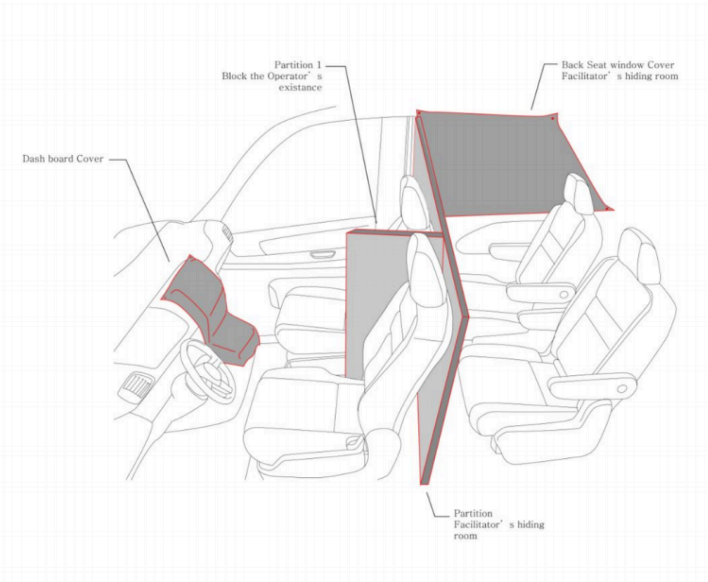


Image 1. 실험 진행 차량 환경 예상도

실험참가자에게는 자율주행에서 탑승하는데에 몰입감을 높이기위해 탑승자의 퍼소나가 주어지게 되며, 주행 시작부터 주행 종료까지 수행해야하는 워크시트와 주행환경을 변화할 수 있는 input command list가 주어집니다. 태스크를 수행하며 필요한 정보와 원하는 정보를 talk-out방식으로 알려주시면 됩니다.

해당 실험에는 3명의 참여자가 존재합니다.
Passenger: 실험의 주체가 되는 탑승자로, 실험 참가자의 역할입니다.
Operator: 자율주행의 시스템을 대체하는 역할로써, 차량 운전과 탑승자가 말로써 표현하는 니즈를 주행에 반영하는 역할을 합니다.
Facilitator: 운전외에 메신저를 통한 탑승자와 소통, 시스템 입력사인, 루트정보, 운행정보, 차량내 엔터테인먼트 요소 조작을 담당하는 역할을 합니다. 차량에 숨어서 탑승자의 눈에 띄지 않습니다.

실험동안 탑승자는 혼자 주행하는 듯한 느낌을 받습니다. Operator와 facilitator와의 쌍방향 소통이 불가능하고 Operator는 사람의 언어가 아닌 종소리로 탑승자의 입력값에 반응하게 됩니다. 해당 반응은 단순입력값 확인으로 사람의 언어로 리액션을 보이지 않습니다.

실험참가자의 반응 및 command정보를 기록하는 녹화가 진행되며, 실험 후 녹화본을 리뷰하며 탑승자의 눈에 띄는 행동과 반응에 대해 다시한번 수기로 정리됩니다. 이는 추후 인터뷰 자료와 함께 자율주행 환경 UI인지정보 분석에 사용됩니다.

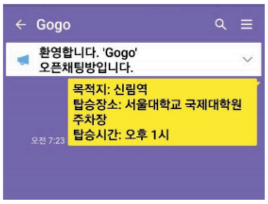
실험에 참가해주셔서 감사합니다.

Gogo 탑승방법
(가상 자율주행 주행 서비스)
실험 과정 안내

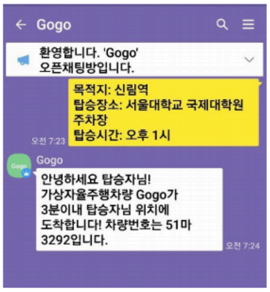
안녕하세요. 자율주행 탑승 서비스 Gogo입니다! 실험 시 사람간 접촉을 최소화하고, 실제 자율주행탑승 시나리오와 비슷하게 진행하기 위하여 메신저를 통해 실험을 시작합니다. 실험 주행 탑승방법은 아래와 같습니다.

1.카카오톡 Gogo 메신저에 들어와주세요.
(링크:https://open.kakao.com/o/sCgu633)

2.메신저를 통해 목적지와 탑승장소 및 시간을 입력해주세요.



3.목적지 도착 3분전, Gogo가 메신저를 통해 도착예정과 차량번호를 알립니다!



4.도착된 Gogo차량을 탑승합니다.

5.메신저를 통해 입력한 목적지가 맞는지 확인하고, 루트를 확인합니다.

6.출발을 명령합니다.

7.주행 중 불편한 사항 혹은 원하는 주행 스타일을 command cue를 활용하여 입력합니다.

8.목적지에 도착!

탑승자 퍼소나

탑승자 상황 상정 및 주행루트

탑승자 관점의 주행 필요인지정보 실험에서 활용될 퍼소나입니다. 퍼소나는 실험참가자가 실험 주행상황을 실제 자율주행 주행환경이라고 생각하며 몰입할 수 있도록 도와주고, 주어진 태스크를 보다 자연스럽게 수행할 수 있도록 도와주는 역할을 합니다.

퍼소나 프로필

Name: Mo

Demographic information: 35세, 현재 회사를 다니며 야간대학원에 재학 중

Occupation: 5년차 데이터베이스 기술영업사원. 월-금까지 가산디지털단지 내에 위치한 회사에서 근무하며 매주 금요일엔 야간 대학원에 다닌다. B2B형태의 영업근무의 특징상 외근이 많고 회식이 많은편. 이번 여름 휴가를 아직 쓰지 못함.

Goal: 고객사와의 우호적인 관계 유지, 내년 진급, 석사과정 수업 충실히 과제제출

상황: 5년차 영업junior사원, 과장과 부장을 포함 10명정도 인원의 팀의 소속, 5년차이지만 후배가 없어 팀에서 막내, 중상정도의 실적을 유지

Technical expertise: 컴퓨터 공학 전공, '기계는 언제나 새것이 좋다'를 신조로 신제품과 신기술에 많은 관심이 있음, 컴퓨터 게임을 즐기지 않으나 인터넷 서핑을 주로하며, 컴퓨터 부품 커뮤니티에서 활발히 활동, 블로그 활동을 함

Hobbies: 넷플릭스로 영화보기, 신제품 검색, 블로그상에서 신제품 리뷰글 올리기, 퍼즐 맞추기, 일기쓰기

History: Mo씨는 장남으로써 책임감을 중요시하며 자랐고, 항상 중상위권을 유지하며 학창시절을 보냈다. 그러나 컴퓨터와 기계에 대해서는 흥미가 넘쳤고 다른 학생들보다 뛰어난 기량을 보였다. 글쓰기에 또한 큰 재능을 보였다. 고등학교때는 지역 사생대회에 학교대표로 출전하기도 하였다. 그는 매일 일기를 썼으며, 그날 배운것과 새로운 게임기 혹은 컴퓨터에 대한 내용에 대해 주로 썼다. 글쓰기는 Mo씨에게 가장 오래된 취미이며 새로운 기계에 대한 관찰은 가장 큰 관심사이다. 대학교에 진학 후 블로그를 처음 접하며 핸드폰부터 컴퓨터까지 가지고있거나 경험하였던 기계에 대한 리뷰를 적기시작했다. 흥미를 살려 컴퓨터공학과로 진학을 하였고, 기술영업 직무로 취직을 하였다.

직장인이 된 후 업무와 회식때문에 신제품 리뷰를 작성할 시간이 적어졌다. 게다가 진급을 위하여 경영학과 야간대학원을 진학 후 더더욱 기계 리뷰를 진행할 시간이 너무 적어졌다.

논문에서 []표시 - Google 검색

Mo씨는 성실하고 열심히 주어진일을 해내는 직장인이다. 그는 항상 출근시간 1시간 전에 출발한다. 직장과 30분 거리에 살지만 예상하지 못한 교통상황에 대비하기 위해서이다. 또한 외근이 많기 때문에 거래처와의 미팅 시간을 미리 잡아 놓는 편이고, 미팅시간보다 항상 일찍 도착하여 관련 자료를 보기위해 미팅시간 1시간 전에 출발하는 것을 선호한다.

대학원에 진학 후 할일이 더욱 많아졌기 때문에 이동시간을 과제리뷰 시간으로 활용하거나, 취미생활인 신제품에 대해 검색해보고, 블로그 글을 쓰는데에 사용하기도 한다.

퍼소나 상황설정

일시: 2018년 금요일

시나리오:

금요일은 회사에서는 오전 근무만을 하고 오후 2시 야간대학원 수업을 수강해야하는 날입니다. 그래서 평소보다 챙길 서류와 소지품이 많습니다. 대학원 강의자료를 챙기고, 오후 1시 서울 도심에서 거래처와 미팅 후 회사로 들어가지 않고 거래처에서 바로 대학원으로 목적지를 설정합니다. 도심에서 멀지않은 거리에 대학원이 위치해있지만 교통량이 많은 교차로를 지나야하기 때문에 속도를 내지 못합니다. 대학원까지 가는 동안 Mo씨는 지난주 수업 내용을 리뷰하고, 과제를 빠르게 습득합니다.

2시 대학원 수업이 끝난 후 6시가 되었습니다. 금요일 오후 수업이기때문에 캠퍼스내 차량이 많지 않습니다. 차량 탑승 후 목적지를 사당에 위치한 집으로 설정합니다.목적지를 집으로 설정하고 차량안에서 잠시 휴식을 취하다가, 새로나온 컴퓨터 장비가 생각나서 핸드폰을 이용해 검색을 하기로 합니다. 동시에 블로그에 간단히 리뷰글을 작성하기로 합니다. 정체때문에 차량은 느리게 주행을 합니다. 서울에서 빠져나와서야 조금씩 속도내기 시작합니다. 퇴근하는 동안 Mo씨는 핸드폰으로 블로그글 초안을 쓰기로 결정합니다. 집에 곧 도착했다는 안내를 듣고 주변 정리 후 차에서 내립니다.

가상 자율주행 루트

재현된 자율주행환경의 주행루트 및 도로타입

본 퍼소나에서 제안된 주행 루트에 따라 주행 동선과 환경을 재현하였습니다. 이동루트와 예상도로상황은 다음과 같습니다. 가상 자율주행은 서울대학교 국제대학원에서 출발하여 서울디지털국가 산업단지를 목적지로 편도 30분/왕복 60분이 소요될 예정입니다.

전체 이동루트

예상 교통량(주행 시간대에 따라 상이)

연구 참여 동의서

귀하는 자율주행 환경에서 탑승자 관점의 필요인지정보 실험에 참여해 달라는 요청을 받으셨습니다.

연구자는 귀하가 이 요청에 동의하시기 전에 다음 사항을 알려주어야 합니다:
(i) 본 연구는 가상 자율주행상황에서 탑승자입장에서 필요로하는 인지정보를 관찰하는것이 목적입니다.
(ii) 본 연구는 실제 도로위에서 Operator가 주행하고, Facilitator가 교통정보를 제공하는 가상 자율주행 차량안에서 이루어집니다.
(iii) 본 연구는 가상 자율주행 실험과 인터뷰로 진행되며, 60분 내외로 끝나는 실험입니다.
(iv) Operator는 교통법규와 규정속도에 맞게 주행하지만, 타 차량으로 인한 교통사고가 발생하지 않도록 최대한 안전하게 운행됩니다.
(v) 실험 진행 중 반응에 대한 기록과 사진촬영, 영상촬영이 이루어집니다.
(vi) 연구논문이외에 관찰 내용과 기록물은 사용되지 않습니다.

또한 연구자는 해당되는 경우 다음 사항을 알려주어야 합니다:
(i) 실험진행 중 컨디션이 좋지 않은 경우 언제든지 실험을 중단할 수 있습니다.
(ii) 관찰을 조금 더 진행해야하는 경우, 실험 기간 혹은 횟수가 늘어날 수 있습니다.
(iii) 실험 방법에 대한 변화 혹은 실험 결과 도출시 귀하에게 알려드립니다.

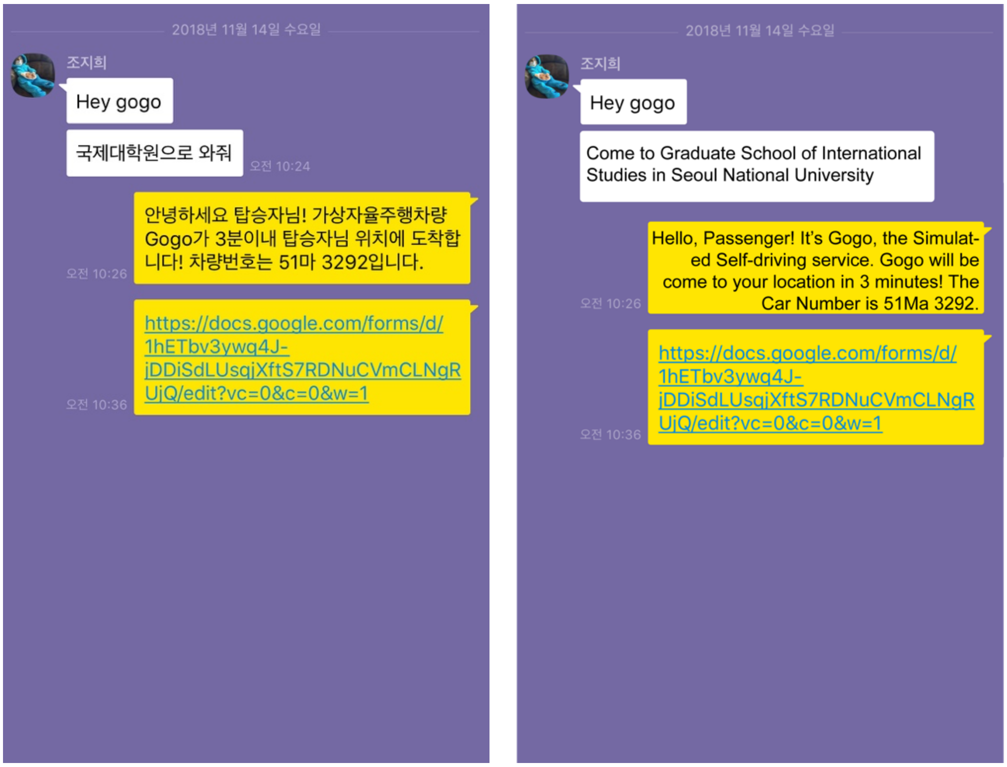
귀하는 이 연구에 대해 질문이 있는 경우 __________ 으로 김현지 에게 연락하실 수 있습니다.
이 문서에 서명하시면 귀하의 참여는 자발적이며, 귀하에게 이 연구(위에 언급된 정보 포함)에 대해 구두로 설명했고, 귀하가 이 연구에 자발적으로 참여하기로 동의한 것으로 간주됩니다.

__________________	__________
참여자 서명	날짜
__________________	__________
입회인 서명	날짜

Appendix 4

[Main Test_ Experiment Log_ Participant 1]
Place: Simulated Autonomous Car, driving from Seoul National University to Seoul Digital National Industrial Complex2
Date: Nov. 14. 2018, 10:30AM

Variables: System response with bib sound.



Calling the car via messenger to remove the human interaction from the beginning of the experiment

(Passenger Getting in the Car)

System: Welcome aboard. It's Autonomous driving service 'GoGo'. If you have any information you desire to know while driving, you can say "Hey, GoGo" and talk-aloud what you want to know. There is a command list on yellow paper above the dashboard. It is the basic commands. If you have any information other than the list, you can freely request the desired information after saying "Hey, GoGo."

System: So, where do you want to go? Please call me "Hey, Gogo" and tell me your destination.

Passenger: Hey, GoGo. Let's go to Seoul Digital National Industrial Complex2.

System: (bip#1) Set the route from Seoul National University Graduate School of International Studies to Seoul Digital National Industrial Complex2. Do you want to check the driving route?

Passenger: Sure. Hey, Gogo, Tell me the route.

System: The recommended route is to go to the Shin-Rim Station from the main gate of Seoul National University and move to the Seoul Digital National Industrial Terminal along the southern ring road. Would you select this route?

Passenger: Hey, Gogo, Is that the shortest route?
System: (bip#1) Yes, this route is the shortest.

Passenger: Okay, then I will select the recommended route.

Passenger: Hey, Gogo, Play Music.
System: (bip#2) (Play music)

Passenger: Hey, Gogo, how long does it take to the destination?
System: (bip#1) It would take about 30 minutes.

(Reading a Book)

System: Please fill out the questionnaires on the front screen in real time.

(look into the screen)

(A problem occurred: the screen does not work)

Passenger: Hey, Gogo, the screen does not work. It is not moving.
System: (bip#1) Sent the survey via messenger. Please check the messenger.

(fill out the survey)

Passenger: Hey, Gogo, please change to the lane to the right.
System: (bip#2) (change lane)

Passenger: Hey, Gogo, please change the lane to the left.
System: (bip#2) (change lane)

Passenger: Hey, Gogo, how far left from here?
System: (bip#1) 5 Minutes to the destination.

(fill out the survey)

System: 3 Minutes are left before the arrival.

(Getting ready to get off. Unbuckle the seatbelt)

(A warning sound goes off)

(buckle the seatbelt again)

Passenger: Hey, Gogo, Please Stop the car along the street.
System: (bip#2)

System: Please input the exact location to stop.

Passenger: Hey, Gogo, Stop anywhere along the street.

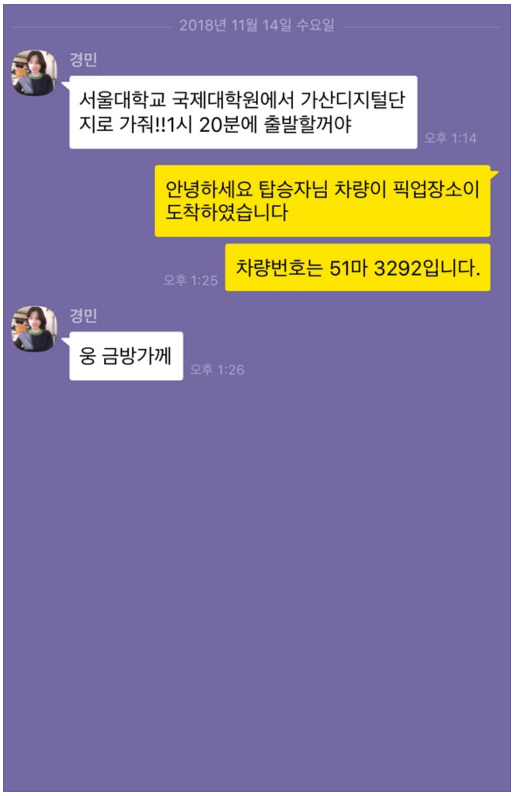
System: (bip#2) (Stop the car, a flicker light turned on)

(Passenger Getting off the car)

Appendix 5

[Main Test_ Experiment Log_ Participant 2]
Place: Simulated Autonomous Car, driving from Seoul National University to Ga-San Digital Complex
Date: Nov. 14. 2018, 13:14 PM

Variables: system response with pre-recorded words to reduce the response gap and give the feeling of immediate reaction, arrival message, stop message that tells the passenger to get off.



Calling the car via messenger to remove the human interaction from the beginning of the experiment

(Passenger getting into the car)

System: Welcome aboard. It's Autonomous driving service 'GoGo'. If you have any information you desire to know while driving, you can say "Hey, GoGo" and talk-aloud what you want to know. There is a command list on yellow paper above the dashboard. It is the basic commands. If you have any information other than the list, you can freely request the desired information after saying “Hey, GoGo.”

Passenger: Hey, Gogo, Let go to Ga-San Digital Complex.

System: Okay. Please wait.
System: Set the route from Seoul National University Graduate School of International Studies to Ga-San Digital Complex. Do you want to check the driving route?

Passenger: Okay.

System: The recommended route is to go to the Shin-Rim Station from the main gate of Seoul National University and move to the Seoul Digital National Industrial Terminal along the southern ring road. Would you select this route?

Passenger: Hey, Gogo, Is that the fastest route without any traffic?

System: okay. Let me check.
System: Yes, it is the fastest.

Passenger: Okay then.

System: Please fill out the questionnaires on the front screen in real time.

(look into the screen)

Passenger: Hey, Gogo, How’s today’s weather? Tell me about the air condition.

System: okay. Let me check.
System: The air condition is good today. dust level is low.

Passenger: Nice, Nice.

Passenger: Hey, Gogo, Play music.

System: Okay, please wait.
(playing song.)

Passenger: Good Choice. I like this music. But why is it in Japanese? You must think I am Japanese.

Passenger: Hey, Gogo, change the music.

System: okay. Please wait.
System: (changed the music)

Passenger: Good! Nice. I like the music. Hey, Gogo, what is title? Who sing it?

System: okay. Let me check.
System: It is song by BTS. Title is DNA.

Passenger: Hey, Gogo, Play Carrol song.
System: okay. Please wait.
System: (Playing Carrol)

Passenger: Hey, Gogo, Is there a traffic? Tell me the traffic information.

System: okay. Let me check.
System: It is smooth from the current location to the Southern Ring Road. It is Stagnated by Traffic in Ganchon Route and it is smooth from Shin Rim.

Passenger: Good.

Passenger: Hey, Gogo, stop the music. It's enough.
System: okay.
System: (Stop the song)

Passenger: Hey, Gogo, Are you a woman or a man?

System: Okay, please wait.
System: I don't have any sexuality.

Passenger: ah, ha!

Passenger: Hey, Gogo, where are we?

System: Okay, please wait.
System: We have entered southern Ring Road.

Passenger: Hey, Gogo, is this road go to Gimpo Airport? is Gimpo Airport Far away from here?

System: okay. Let me check.

System: This road head to the Gimpo Airport, but the distance is quite far.

Passenger: Hey, Gogo, please change the lane to the left.

System: Okay.
System: (Changed the lane)

Passenger: Hey, Gogo, how long does it take to arrival from here?

System: Okay. Let me check.
System: 5 minutes before destination.

(stuck in Traffic)

Passenger: Hey, Gogo, you said only 5 minutes left. But it takes longer than that.

System: Okay. Let me check.
System: It was delayed due to the traffic. We are now 300 meters from the arrival.

Passenger: Hey, Gogo, please drive safe.

System: Okay.
System: I keep the safe regulation for speed.

System: 3 minutes before arrival.

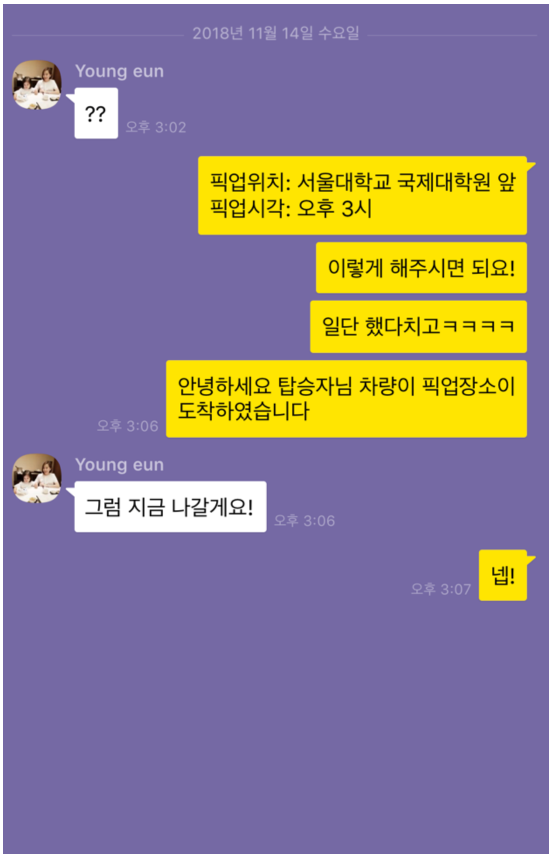
Passenger: um... where to stop…Hey, Gogo, stop wherever that can be stopped by the road.

System: The vehicle arrived at the destination.
System: I am looking for a stop.

Appendix 6

[Main Test_ Experiment Log_ Participant 3]
Place: Simulated Autonomous Car, driving from Seoul National University to Boramea Park.
Date: Nov. 14. 2018, 15:00 PM

Variables: Changed destination. system response with pre-recorded words to reduce the response gap and give the feeling of immediate reaction. Live input of system dialogue. arrival message stop message that tells the passenger to get off.



Calling the car via messenger to remove the human interaction from the beginning of the experiment

(Passenger getting into the car)

System: Welcome aboard. It's Autonomous driving service 'GoGo'. If you have any information you desire to know while driving, you can say "Hey, GoGo" and talk-aloud what you want to know. There is a command list on yellow paper above the dashboard. It is the basic commands. If you have any information other than the list, you can freely request the desired information after saying “Hey, GoGo.”

System: So, where do you want to go? Please call me “Hey, Gogo” and tell me your destination.

Passenger: Hey, Gogo, Let’s go to Boramea Park.

System: Okay.
System: Set the route from Seoul National University Graduate School of International Studies to Boramea Park.

Passenger: Hey, Gogo, Tell me the route.

System: Okay. Please wait.
System: The recommended route is to go to Shin rim Station and to Boramae Hospital.

Passenger: Hey, Gogo, it is hot in here. I can open the window, right?

System: Okay. Please wait.
System: Let me open the window.

System: Please fill out the questionnaires on the front screen in real time.

(reading the survey)

Passenger: (reading the survey out loud) this questionnaire records your answer in real time… if certain information is desired strongly… desired by who? Me? Hey Gogo?

System: Yes, by the passenger.

Passenger: Speed, If I felt the speed fast then do, I check for speed? Hey Gogo?

System: If you wish to know the speed information, you can check the for the speed.

Passenger: Hey, Gogo, how long does it take to the destination?

(delay)

Passenger: who answers me…?

System: Okay. Let me check.
System: It is expected to take 15 minutes to Boramae Park.

Passenger: 15 minutes! Then there will be no traffic then.

(taking a turn)

Passenger: Oh, we are going to this way.

(checking the survey)

Passenger: So, is this the faster way to the destination? Hey, gogo?
Passenger: I was thinking about the different route. But there supposed to be a different way?

System: Okay. Let me check.
System: It is the shortcut.

Passenger: So, the driving route is the round trip, right Gogo?

System: Please say the command with the command cue.

Passenger: Please tell me the driving route. (politely)

System: you can say like “hey, gogo” and say what you want to know.

Passenger: Hey, Gogo, Tell me the current Traffic information.

System: Okay. Please wait.
System: The current route runs smoothly.

Passenger: Hey, Gogo, what is the closest station from here?

System: Okay. Let me check.
System: It is the Seoul National University Entrance Station.

Passenger: Hey, Gogo, how long since we departed?

System: Okay. Let me check.
System: it has been 5 minutes.

Passenger: ah, ha

Passenger: Hey, Gogo, how fast are we driving?

System: Okay. Let me check.
System: We are driving at 40 km/h.

Passenger: oh, it felt faster. And I feel nausea. I don't know why. Is it because I am not actually driving by myself?

Passenger: How long before the arrival? Hey Gogo, How long before the arrival?

System: Okay. Let me check.
System: We are just arrived at the destination.

System: Please tell me where to stop.

Passenger: um... I don't know... Hey, Gogo, is there a parking lot nearby here?

System: Okay. Let me check.
System: There is three parking lot around here.

Passenger: Hey, Gogo, what is the closest one?

System: Okay. Let me check.
System: The closest one is 50m from here.

Passenger: Hey, Gogo, Can you tell me the price of the parking?

System: Okay. Let me check.
(time taking…)

Passenger: Um…Hey, Gogo, Just stop over here, beside the sidewalk.

System: Okay.
System: The car is now stopped at the destination. You can get off the car now.

(getting off the car.)

Appendix 7

[Main Test_ Experiment Log_ Participant 4]
Place: Simulated Autonomous Car, driving from Seoul National University to Ga-San Digital Complex
Date: Nov. 14. 2018, 15:00 PM

Variables: system response with pre-recorded words to reduce the response gap and give the feeling of immediate reaction. Live input of system dialogue

Calling the car via messenger to remove the human interaction from the beginning of the experiment

System: Welcome aboard. It's Autonomous driving service 'GoGo'. If you have any information you desire to know while driving, you can say "Hey, GoGo" and talk-aloud what you want to know. There is a command list on yellow paper above the dashboard. It is the basic commands. If you have any information other than the list, you can freely request the desired information after saying "Hey, GoGo."

System: So, where do you want to go? Please call me "Hey, Gogo" and tell me your destination.

Passenger: Hey, Gogo, Let's go to Boramea Park.

System: Okay.

System: Set the route from Seoul National University Graduate School of International Studies to Boramea Park.

Passenger: Hey, Gogo, Tell me the route.

System: Okay. Please wait.
System: The recommended route is to go to Shin rim Station and to Boramae Park.

System: Please fill out the questionnaires on the front screen in real time.

(looking at the survey)

Passenger: Hey, Gogo, Tell me the current traffic.

System: Okay. Please wait.
System: The current traffic runs smoothly.

Passenger: Hey, Gogo, Play music.

System: Okay. Please wait.
(playing music)

Passenger: Hey, Gogo, change it to radio.

System: Okay. Please wait.
(playing radio)

(…driving…)

Passenger: Hey, Gogo, please drive safe.

System: Okay.
(down the driving speed)

Passenger: Hey, Gogo, what is the current location?

System: Okay. Please wait.
System: The current location is 2/3of the total route. We are now on Gwancheon Road.
Passenger: Hey, Gogo, what is the remaining driving time?

System: Let me check.
System: 10 minutes left.

Passenger: Hey, Gogo, how long do we have to go?

System: Okay. Let me check.
System: 5 minutes left.

System: 3 minutes before arrival.

Passenger: um... Hey, Gogo, stop nearby the car to the right.

System: Okay.

Passenger: Hey, Gogo, Change lane to the right.

System: Okay.
System: The vehicle arrived at the destination.
(the car stops)

(the passenger gets off the car.)

Bibliography

Abraham, H., Reimer, B., Seppelt, B., Fitzgerald, C., Mehler, B., & Coughlin, J. F. (2017). *Consumer Interest in Automation: Preliminary Observations Exploring a Year's Change* (Rep.). MA: White Paper, Age Lab, MIT.

Alessandrini, A., Campagna, A., Site, P. D., Filippi, F., & Persia, L. (2015). Automated Vehicles and the Rethinking of Mobility and Cities. *Transportation Research Procedia,5*, 145-160. doi:10.1016/j.trpro.2015.01.002

Autonomous Car Development Platform from NVIDIA DRIVE PX2. (n.d.). Retrieved from https://www.nvidia.com/en-us/autonomous-cars/drive-platform/

Bagloee, S. A., Tavana, M., Asadi, M., & Oliver, T. (2016, August 29). Autonomous vehicles: Challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation,24*(4), 284-303. doi:10.1007/s40534-016-0117-3

Bernsen, Niels Ole, Hans Dybkjær, and Laila Dybkjær. "Wizard of oz prototyping: How and when." *Proc. CCI Working Papers Cognit. Sci./HCI, Roskilde, Denmark* (1994).

Bonnefon, J., Shariff, A., & Rahwan, I. (2016). The social dilemma of autonomous vehicles. *Science,352*(6293), 1573-1576. doi:10.1126/science.aaf2654

Bosch Global. "Automated Valet Parking - Don't Get Stressed, Get Parked." *Bosch Global*, 19 Dec. 2018, www.bosch.com/stories/.

BUCHHOLZ, K. (2018, February 21). Adient rethinks interior technology for autonomous vehicles. Retrieved from https://www.sae.org/news/

Card, Stuart K., et al. *The Psychology of Human-Computer Interaction*. Lawrence Erlbaum Associates, Inc., 1983.

Choi J.W.,Park H.S.,Kim K. H., "The Modal Selection for Human Vehicle Interface to Provide Information with Drivers", Ergonomics Society of Korea Conference Proceedings/ 2010(5), 2010., 254-257, Ergonomics Society of Korea

Chen, Z., He, F., Yin, Y., & Du, Y. (2017, May). Optimal design of autonomous vehicle zones in transportation networks. *Transportation Research Part B: Methodological,99*, 44-61. doi:10.1016/j.trb.2016.12.021

Clark, B., Parkhurst, G. and Ricci, M. (2016) Understanding the Socioeconomic Adoption Scenarios for Autonomous Vehicles: A Literature Review. Project Report. University of the West of England, Bristol. Available from: http://eprints.uwe.ac.uk/29134

Cudak, G. D., Hardee, C. J., & Rodriguez, A. X. (2017). *U.S. Patent No. US 9,567,007 B2*. Washington, DC: U.S. Patent and Trademark Office.

Cuddihy, M. A., & Rao, M. K. (2015). *U.S. Patent No. US 9,199,553 B2*. Washington, DC: U.S. Patent and Trademark Office.

"Dashboard." Def.2. *Merriam-Webster.com*. Merriam-Webster Dictionaries. 18 Nov.2018

Daum UX Lab. "[Method] Wizard of Oz Prototyping." *Daum UX Lab*, TISTORY, 8 Jan. 2009, uxtlab.tistory.com.

DeMuro, D. (2018, January). 7 Best Semi-Autonomous Systems Available Right Now. Retrieved from https://www.autotrader.com/

Driver Workload Metrics Project: Task 2 Final Report. (2006 Nov). (Report No. DOT HS 810 635). Washington, DC: National Highway Traffic Safety Administration.

Dumas, Joseph S., and Janice Redish. *A Practical Guide to Usability Testing*. Intellect, 1999.

Endsley, Mica R. "Toward a Theory of Situation Awareness in Dynamic Systems." *Human Factors: The Journal of the Human Factors and Ergonomics Society*37 (n.d.): 32–64(33). In Print.

Endsley, M. R. (1999). Level of automation effects on performance, situation awareness and workload in a dynamic control task. *Ergonomics,42*(3), 462-492. doi:10.1080/001401399185595

Endsley, M. R. (1988). Design and Evaluation for Situation Awareness Enhancement. *Proceedings of the Human Factors Society Annual Meeting*, *32*(2), 97-101. https://doi.org/10.1177/154193128803200221

Endsley, M. R. (1999). Situation awareness in aviation systems. In D. J. Garland, J. A. Wise, & V. D. Hopkin (Eds.), **Human factors in transportation. Handbook of aviation human factors** (pp. 257-276). Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice,77*, 167-181. doi:10.1016/j.tra.2015.04.003

Federal Automated Vehicles Policy: Accelerating the Next Revolution In Roadway Safety. (2016, Sep) Washington, DC: National Highway Traffic Safety Administration.

Gartner, Inc. (2014, October 8). Gartner Identifies the Top 10 Strategic Technology Trends for 2015. Retrieved from www.gartner.com

Google X. (n.d.). Waymo. Retrieved from http://waymo.com/

Google X. "Journey – Waymo." *Waymo*, http://waymo.com/journey/.

Hars, A. (2015, April 10). Self-Driving Cars: The Digital Transformation of Mobility. *XPERT.PRESS,*539-549. doi:10.1007/978-3-662-43782-7_57

Hsu, J. (2016, March 07). 75% of U.S. Drivers Fear Autonomous Cars, But It's an Easy Fear to Get Over. Retrieved August 6, 2018, from https://spectrum.ieee.org/

Jae Yong, Lee. “What Is Model Human Processor (MHP)?” *Pxd UX Lab.*, TISTORY, 6 July 2014, story.pxd.co.kr.

Jack Boeglin, **The Costs of Self-Driving Cars: Reconciling Freedom and Privacy with Tort Liability in Autonomous Vehicle Regulation**, 17 YALE J.L. & TECH (2015).
Available at: https://digitalcommons.law.yale.edu/yjolt/vol17/iss1/4

Jess Macy Yu, “Chipmaker Nvidia's CEO sees fully autonomous cars within 4 years”, The Thomson Reuters Trust Principles, 2017

Joon-Hwan, Lee, and Jun Soo-Jin. "Design Guidelines and Recommendations for In-Vehicle Navigation Systems." *Archives of Design Research* 23.3 (2010): 309-327.

Kabbaj, Wanis. “What a Driverless World Could Look Like.” *Ted*, Ted, www.ted.com/talks/.

Knoll, P. M. (2017). Some pictures of the history of automotive instrumentation. *Journal of the Society for Information Display,25*(1), 44-52. doi:10.1002/jsid.536

Lee, J. D., Moeckli, J., Brown, T. L., Roberts, S. C., Schwarz, C., Yekhshatyan, L., Nadler, E., Liang, Y., Victor, T., Marshall, D., & Davis, C. (2013, May). Distraction Detection and Mitigation Through Driver Feedback: Appendices. (Report No. DOT HS 811 547B). Washington, DC: National Highway Traffic Safety Administration.

Lee. J. S. "Human Factors in Driver's Speed Control and Information Processing: Effect of Driver's Eye-Level and Cognitive Load." Korea Journal of Experimental and Cognitive Psychology, 8.2 (1996): 345-366. Print.

Lynberg, M. (2018, April 13). Automated Vehicles for Safety. NHTSA in action, Retrieved from https://www.nhtsa.gov/

Marinik, A., Bishop, R., Fitchett, V., Morgan, J. F., Trimble, T. E., & Blanco, M. (2014, July). Human factors evaluation of level 2 and level 3 automated driving concepts: Concepts of operation. (Report No. DOT HS 812 044). Washington, DC: National Highway Traffic Safety Administration.

Morgan Stanley Research. (2013). *Autonomous Cars: Autonomous the New Auto Industry Paradigm* (Rep.). Morgan Stanley Blue Paper.

Morello, L., Rossini, L. R., Pia, G., & Tonoli, A. (2011). *The Automotive Body Volume I: Components Design*. Dordrecht: Springer Netherlands.

Nees, M. A. (2016, September 15). Acceptance of Self-driving Cars. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting,60*(1), 1449-1453. doi:10.1177/1541931213601332

Ohn-Bar, E., & Trivedi, M. M. (2016, March). Looking at Humans in the Age of Self-Driving and Highly Automated Vehicles. *IEEE Transactions on Intelligent Vehicles,1*(1), 90-104. doi:10.1109/tiv.2016.2571067

Pak, R. (2018, January 29). Changing views of autonomous cars... [Web log post]. Retrieved from https://www.humanautonomy.com/

"Pittsburgh, Your Autonomous Uber Is Arriving Now." *Driver Requirements | How To Drive With Uber | Uber*, 14 Sept. 2016, www.uber.com/.

Preliminary Statement of Policy Concerning Automated Vehicles. Washington, DC: National Highway Traffic Safety Administration.

Rubin, Jeff, and Dana Chisnell. *Handbook of Usability Testing, Second Edition: How to Plan, Design, and Conduct Effective Tests*. Second ed., Wiley Publishing, Inc., 2008.

Staff, 24/7. "Is Amazon Creating Autonomous Cars for Delivery? - Supply Chain 24/7." *Supply Chain 24 7*, 24 Apr. 2017, www.supplychain247.com/.

Survey: More Americans Willing To Ride In Autonomous Cars. (2018, January 27). Retrieved August 8, 2018, from https://detroit.cbslocal.com/

Seoul Solution. (2018, March 06). [Metro] Seoul's Subway Project for Sustainable Safety. Retrieved from https://www.seoulsolution.kr/en/content/3574

Shimojo, S., Shams, L., Sensory modalities are not separate modalities: plasticity and interactions, Curr. Opon. Neurobiol., Vol. 11, pp. 505-509, 2001.

Soegaard, Mads, et al. *Encyclopedia of Human-Computer Interaction*. 2nd ed., Interaction Design Foundation, 2013.

Sethumadhavan, Arathi. "Dr. Mica Endsley: Current Challenges and Future Opportunities In Human-Autonomy Research." *HUMAN-AUTONOMY SCIENCES*, 8 Dec. 2017, www.humanautonomy.com/.

Sethumadhavan, A. (2011). Effects of first automation failure on situation awareness and performance in an air traffic control task. *PsycEXTRA Dataset*. doi:10.1037/e578902012-072

Telpaz, A., Rhindress, B., Zelman, I., & Tsimhoni, O. (2015, September 01). Haptic seat for automated driving. *Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications - AutomotiveUI 15*. doi:10.1145/2799250.2799267

Thompson, C. (2015, November 18). Volvo's new driverless concept car has modes for 'drive,' 'create,' and 'relax'. Retrieved from https://www.businessinsider.com/

A Study on Improvement of Driver's License Test for the Driver's Safe Driving. (pp. 63-119, Rep.). (2015). National Police Agency in Republic of Korea.

The National Highway Safety Administration, "Preliminary Statement of Policy Concerning Automated Vehicles", 2016

Thompson, Cadie. *Here's How Tesla's Autopilot Works*. 1 July 2016, www.businessinsider.com.

Traffic Safety Facts: Research Note. Appendices. (2017 Oct). (Report No. DOT HS 812 456). Washington, DC: National Highway Traffic Safety Administration.

Victor, T., Engström, J., & Harbluk, J. (2008). Driver Distraction: Theory, Effects, and Mitigation. *Distraction Assessment Methods Based on Visual Behavior and Event Detection,*136-161. doi:10.1201/9781420007497.ch10

Watanabe, K., & Shimojo, S. (2001). When Sound Affects Vision: Effects of Auditory Grouping on Visual Motion Perception. *Psychological Science,12*(2), 109-116. doi:10.1111/1467-9280.00319

Xiang, H., & Tian, L. (2011, February). Development of a low-cost agricultural remote sensing system based on an autonomous unmanned aerial vehicle (UAV). *Biosystems Engineering,108*(2), 174-190. doi:10.1016/j.biosystemseng.2010.11.010

국문 초록

'탑승자'의 관점의 시간, 위치 기반 차량 클러스터 UI 디자인 프레임 제안 연구

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사용자 인터페이스가 (UI) 미래 이동성에서 새로운 사용자 역할을 지지하는 디자인 도출은 미래 이동성 분야에서 중요한 디자인 이슈이다. 그러나 사용자 실험에 근거하여 자율주행차량 (AV) 의 탑승자인지 욕구와 행동에 대한 디자인 연구는 미미하다. 자율주행이 기술의 발전과 그 영역은 점차 넓어지고 있다. 해당 기술은 이미 운전 환경에 적용되고 있으며, 이로 인해 미래 이동문화에서 사용자의 역할은 '운전자'에서 '탑승자'로 변화한다. 본 연구는 미래 자율주행차량이 모든 운전 상황에 대처할 수 있다는 것을 전제로 한다. 사용자 실험을 통해 탑승자의 관점에 대한 분석을 진행하였고, 이를 기반으로 미래 모빌리티 환경에 적용될 사용자 인터페이스를 제안한다. 제안된 디자인은 운전자 중심의 상황인지에서 벗어나 탑승자 중심 인지 정보 요소를 분석하였고, 시간과 경로 두 가지 요소를 강조한 UI 를 제안한다.

본 연구에서 탑승자의 인지 정보 요구에 대한 실험적 데이터를 수집하였다. 탑승자의 관점을 이해하기 위해 다양한 관점에서 인간의 인지적

특성 및 운전 태스크를 관찰하였고, 상황인지 (SA) 에 관한 문헌 연구와 데이터 프레임워크 구조화를 통해 운전 환경에서 발생하는 인지적 요소 관계를 분석하였다. 제안된 프레임워크는 기술 변화에 따라 운전자가 탑승자로 변화되었을 때 운전 환경에서의 데이터 관계 변화를 시각적으로 구조화하여 심층적으로 탐구되었다. 탑승자의 인지 니즈 대한 실험적 데이터베이스를 수집하기 위해 총 3 세트의 유저 테스트와 심층 인터뷰가 수반되었다. 유저 테스트는 Wizard of Oz 방법을 사용하여 설계되었으며 실험 결과는 질적 연구방법론의 분석 방법을 통해 분석되었다. 실험을 통해 얻은 인사이트를 바탕으로 탑승자 관점에서 UI 디자인을 제안하고 사용성 테스트를 통해 효율성과 유용성을 5 점 리 커트 스케일로써 검증하였다.

실험 결과에 따르면 탑승자가 요청한 인지 정보는 시간 (현재 시각 및 기간)과 경로 (차량 위치 및 주변 환경)에 집중된 것을 관찰할 수 있었다. 이와 같은 데이터를 기반으로 UI 프레임워크를 구성하였다. 상황 속의 사용례를 제시하기 위하여도 가지 time-full 과 time-less 의 사용 시나리오를 구축하고, 제안된 시나리오에 따라 시간과 위치에 기반한 UI 를 제안하였다. 제안된 UI 에 대한 사용성 테스트를 진행하였고, 탑승자 관점에서의 운전상황 인지 워크 프레임을 완성하였다. 본 연구의 가치는 두 가지로 정리될 수 있다. 하나는 운전자 / 탑승자의 데이터 플로우 프레임워크를 제안하였다는 것과 두 번째는 탑승자의 관점을 지지하는 UI 디자인 제안에 있다. 운전자의 관점에서의 운전 상황을 분석하여 사용자, 차량, 그리고 도로 상태 간의 관계를 시각화하였고, 이는 탑승자인지 플로우 프레임워크를 제안하는데 기조적인 틀로써 사용되었다.

본 연구는 운전 태스크를 수행하는 데에 필요했던 인지 부담에서 벗어났을 때의 운전자가 필요로 하는 복합적인 니즈에 대해 관찰하고 미래 모빌리티 환경에 적합한 UI 의 디자인 요소에 대한 연구논문이다. 미래 자율주행차량 안의 사용자 인터페이스가 갖추어야 하는 요소를 실험적 데이터에 근거하여 제시하며, 시간과 루트를 강조하여 향상된 상황 인지를 제공하는 방법에 대한 심도있는 관찰을 기록한다. 본 연구는 질적 연구에 기초한 자율 차량의 탑승자 관점을 관찰함으로써 기존 자율주행이 디자인 연구에 기여할 것이다. 제안된 UI 디자인 미래 이동 성안에서 시스템과 탑승자 간의 커뮤니케이션 방법에 대한 연구로써 그 의의가 있다.

주요어: 탑승자 중심 클러스터 UI; 데이터 플로우 워크프레임; 자율주행차량; 상황인지; 수동적 유저

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