공학석사학위논문

Comparing Different Media for Autonomous Vehicle Product Description: Information Transfer and Trust Change

자율주행 차량 제품 설명의 매체 비교 연구 : 매체에 따른 정보 전달과 신뢰 변화 차이

2021 년 2 월

서울대학교 대학원
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한 두 원

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지도교수 박 우 진

이 논문을 공학석사 학위논문으로 제출함

2020 년 12 월

서울대학교 대학원

산업공학과

한 두 원

한두원의 공학석사 학위논문을 인준함

2020 년 12 월

위 원 장	윤 명 환	(인)
부위원장	박 우 진	(인)
위 원	장 우 진	(인)

Abstract

Comparing Different Media for Autonomous Vehicle Product Description: Information Transfer and Trust Change

Doowon Han

Department of Industrial Engineering

The Graduate School

Seoul National University

In this thesis, we consider how the expression of autonomous vehicle product information can be improved in terms of memory, learning workload, and trust in automation. We investigate the solution by comparing different medium types and presentation orders. As a result, we propose a design recommendation guideline that can be used in designing autonomous vehicle product education materials and assist in trust calibration.

Keywords: Autonomous vehicle, Trust in automation, Information transfer

Student Number: 2019-26296

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Chapter 1

Introduction

The advent of autonomous vehicles and systems has raised several interests among people. The concept that the vehicle drives itself has shed light on unskilled drivers and non-drivers. Further, it offers idle time for normal drivers to concentrate on other activities. Semi-autonomous vehicles which correspond to between level 2 (Partial automation) and 3 (Conditional automation) according to Society of Automotive Engineers(SAE) International standards is being released in the market[16]. Many semi-autonomous vehicles are currently being operated on the road and there are indications that by 2060, half of the vehicle fleet will be autonomous vehicles[22].

Since semi-autonomous vehicles cannot handle driving completely, the driver must engage in certain situations. This brings attention to the driver's behavior during semi-autonomous driving since switching to manual driving from autonomous driving (aka. takeover) relies heavily on what the driver was doing. Especially, the interaction and trust between the driver and the autonomous system are crucial when a takeover request occurs as it influences the user behavior. Keeping the driver inside the system and understanding how user trust fluctuates are the main focus of safely applying incomplete autonomous driving such as level 3 autonomous vehicles.

With the situations of driving requiring the users to be inside the system and the fact that users are not familiar with the newly implemented functions of autonomous vehicles, users must be provided with information beforehand to appropriately operate the autonomous vehicle system and form trust. Past research results emphasize the importance of understanding the technology of the system before operation [25]. Actual use and experience can promote the understanding of the system but in the case of driving autonomous vehicle, the consequence of mistake and failure can lead to damage of users. The understanding of the system can be also achieved through education without the risk of damage. Education of autonomous vehicle product description can offer prior knowledge to users who have not yet encountered the autonomous vehicles and increase the degree of understanding of situations while driving. California Department of Vehicle (DMV) has specified the need for autonomous vehicle training on the regulation of autonomous vehicle testing[6]. They stated that the driver must be experienced and the manufacturer of the autonomous vehicles must maintain a training program with the contents including capabilities and limitations of the automated driving systems. However, only the training program curriculum is required and detailed requirements of how the training should be carried out are not clearly elucidated and this lead to individual training from 66 companies currently conducting research on autonomous vehicles in California. Even with the necessity of education, no policies are currently guiding how education should be carried out, which is forming an arbitrary curriculum reliant on each of the autonomous vehicle manufacturers.

The absence of proper education guidelines can lead to a lack of system information in users. The lack of information can result in misbehavior or missing proper behavior while driving. Also, lack of information causes misconception which generates disuse and misuse by influencing trust in automation[20]. Additionally, the lack of research on the education of autonomous vehicles can generate an inefficient way of training and ineffective way of delivering information. The misconception of an autonomous vehicle not only influences trust but also affects users to be deceived by their own assumptions[21].

Despite previous research efforts, a research gap still seems to remain in selecting the appropriate form of education material such as medium type and presentation order for a better learning performance and calibrate trust. The findings of the medium effect on learning are very inconsistent and out of date that needs to be verified with an additional medium type. Additionally, lack of research results in the effect of presentation order brings the necessity of verification. Relatively little research has been conducted to explain the different effects of the medium on trust with identical contents.

In an attempt to fill the knowledge gap, the objective of the current study is to investigate the effects of medium type and presentation order of information on learning performance, learning task workload and automation trust. The research questions to address the study objectives are shown below.

1. Will the medium type and presentation order affect memory recall?

2. Will the medium type and presentation order affect memory retention over time?

3. Will the medium type and presentation order affect subjective rating of learning task workload?

4. Will the medium type and presentation order affect trust change due to exposure to autonomous vehicle product information?

5. Will the medium type and presentation order affect trust change due to time lapse?

The first and second research question is aimed to discover how the autonomous vehicle information can be efficiently delivered at the moment people are exposed to the information and better retained over time. If there are no difference between medium type and presentation order in terms of memory recall and retention, identifying the result of third research question will guide to efficient and appropriate education method. The objective of fourth and fifth research question is to establish a foundation in finding an appropriate trust level that can promote safety in automation human relationship by investigating how trust changes through exposure to information and education.

The thesis is composed of 6 chapters. In Chapter 2, we review literatures related to media learning and trust in automation. In Chapter 3, an explanation of the experimental method is stated. In Chapter 4, the results of the experiments in terms of memory, learning workload and trust are presented. In Chapter 5, interpretations of the main findings and implications of the results are mainly discussed along with limitations and future research directions of the thesis. Finally, in Chapter 6, a brief conclusion and a takeaway of the thesis is presented.

Chapter 2

Literature Review

2.1 Level of Autonomous Vehicle by SAE

The vehicles that are currently released with automation are classified with certain standards. The standard established by SAE classifies automotive vehicles into 6 levels from level 0 to level 5. With each level representing minimum capabilities of the vehicles. The difference between level 2 (Partial automation) and level 3 (Conditional automation) is whether the subject who is in charge of the monitoring of driving environment is human driver or the system. The representative function that that is relevant to partial automation is the driver assistant function related to steering and acceleration/deceleration. The name of the driver assistant technology may vary by the manufacturers, but the basic technology within is the lane-keeping assist system (LKAS) and forward collision-avoidance assist (FCA). LKAS can support the driver with maintaining the driving lane by steering operation and FCA can support the driver with automatic emergency braking by decelerating in a potential collision situation. Depending on the level of technology that the manufacturer supports, LKAS can assist from lane departure alarm to maintaining the driving lane automatically. Also, FCA can assist from forward collision warning to automatic emergency braking. Other assistant function such as adaptive-cruise control (ACC), automated parking, and autopilot in several situations are considered as conditional or high automated driving modes which can be applicable to level higher than 2. Currently, many vehicles released in public correspond to level between 2 and 3 supporting LKAS, FCA, and adaptive cruise control. The driving technology that is currently released by many vehicle manufacturers with their own name is stated at the Appendix A.

2.2 Media Learning

Several research endeavors have been conducted towards the effect of medium on education and trust. For example, there have been many controversies whether medium type affects education performance. A few studies done by Kulik and his coworkers have investigated the effect of mediums in a classroom environment[8, 17, 18, 19]. Also, based on the work done by Kulik, a meta-analysis done by Clark has shown that the medium itself does not affect the learning, and the instruction method is more that matters (Clark, 1983). A counter opinion to the assertion that medium does not affect learning is stated in other studies and critique as well criticizing that the meta-analysis from Clark is only limited to classroom environment[24] and the difference in encoding operation resulting from each medium attributes can play a central role in what information can be presented[2, 3].

2.3 Trust in Automation

Many studies related to trust in automation have put an effort to define trust and appropriate level of calibrated trust in automation. With the definition of trust considered to be an attitude of a user towards an agent that will help fulfill the purpose in a situation with uncertainty and vulnerability[20], several studies have investigated the effect of autonomous driving experience and information on human trust. It is discovered that prior knowledge without direct experience can affect trust in automation[15] and that leaving out information of automation limitation leads to increased trust[13], but decreases and did not recover in case accidents occurred[1]. Another study has conducted research to find the difference between a virtual simulation of highly automated driving and other types of mediums in terms of the perception of autonomous vehicles. Their findings stated that experience in the driving simulator lead to a negative perception in the aspect of trust and discomfort[9].

Chapter 3

Method

3.1 Participants

A total of 60 participants were recruited through university community. Two of the participants had prior experience to the lane-keeping assist system (LKAS) and forward collision-avoidance assist (FCA). None of the participants had prior experience to level 3 autonomous driving and driver license was not a necessary requirement.

Table 3.1: Demographic information of participants

		Gender		Age		Driving experience (distance)		Driving experience (year)	
	Sample Size	Male	Female	Mean	S.D	Mean	S.D	Mean	S.D
Overall	60	37	23	29.26	7.75	20828.33	66292.58	3.92	7.48
Text	20	15	5	29.11	8.72	19957.00	48295.04	5.46	9.28
Video	20	11	9	29.10	8.30	24961.00	100481.81	2.79	7.79
Simulator	20	11	9	29.55	6.58	17567.00	34463.59	3.51	4.82

Total of 60 participants, 37 males and 23 females were considered for analysis with the ages between 21 and 61 years (M = 29.26, SD = 7.75). On average, they had a driving experience of 20828km in distance (See Table 3.1). The participants were each randomly assigned with one of three mediums of text, video, and simulator. The participants' distance of driving experience was equally distributed among groups.

3.2 Medium – Presented Instruction Format

A total of 3 mediums were used to explain the situations of autonomous vehicle driving. The text was displayed similar to the car product instruction using a bullet point format. The video was displayed with a 3rd person point of view at the rear position. The simulator was displayed with one channel visualizing the forward 1st person point of view and two channels visualizing each side 1st person point of view (see Figure 3.1).

Figure 3.1: Experimental setup of simulator

3.3 Contents - Driving Scenario Situations

The contents of each medium consisted of eight scenarios with four capabilities describing a situation where the autonomous vehicle can handle by itself and four limitations describing a situation where the autonomous vehicle cannot handle by itself. A description of each capability and limitation situations is as follows:

- Traffic aware cruise control: the vehicle drives on a highway and passes a slowly driving vehicle in front considering the surrounding situations.
- Car cut-off: the vehicle rapidly brakes when another vehicle suddenly cuts in in front.
- Traffic light intersection: the vehicle stops at a red traffic light and proceeds at a green traffic light
- Off ramp in highway: the vehicle advances towards the ramp to get off the highway.
- General line missing: in a situation where the line on the road is missing, the vehicle requests a takeover eight seconds before the missing lane.
- Road construction: in a situation where there is a road construction zone, the vehicle requests a takeover eight seconds before the road construction.
- Curved line missing: in a situation where the line on the curved road is missing, the vehicle requests a takeover eight seconds before the missing lane.
- Rain: in a situation where heavy rain falls and the road is covered with water, the vehicle requests a takeover.

Each capability and limitation scenarios represents a realistic situation from a currently released semi-autonomous vehicle (Tesla model 3) and a disengagement report from the California DMV.

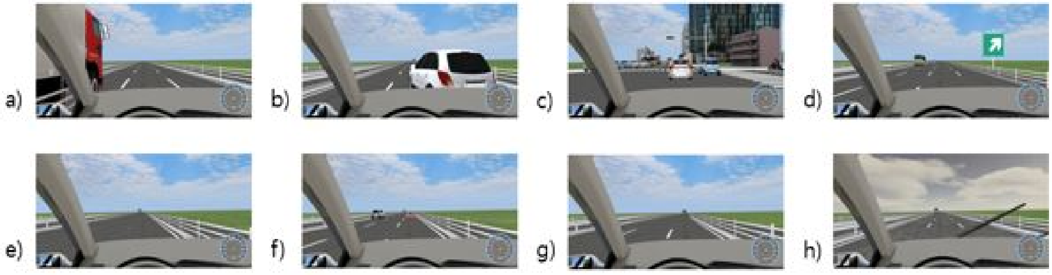


Figure 3.2: a) Traffic aware cruise control, b) Car cut-off, c) Traffic light intersection, d) Off ramp in highway, e) General line missing, f) Road construction, g) Curved line missing, h) Rain

3.4 Procedure

Prior to the experimental session, each participant is randomly assigned with a medium at the start of the experiment depending on the distance of participants' driving experience followed with a general description including the purpose of the experiment and a detail information of the questionnaires was explained prior to the experimental trial. After the explanation, the participants were given a trust questionnaire to evaluate their initial trust in the autonomous vehicles based on their knowledge and impression. The experimental session consisted of two trials, with trial 1 showing paper-based scenario information for 5 minutes regardless of the medium type (Initial text presentation, Appendix B) and trial 2 showing the same scenario contents visualized with different mediums for approximately 5 minutes depending on the assigned medium type (Medium presentation). In a medium presentation, the explanation of the scenario situations was given verbally through an electronic voice in all 3 mediums. For the group assigned with text and video, the corresponding information to the scenario situation was presented afterward with the designated medium type(Appendix C, D). For the group assigned with a simulator, participants were allowed to adjust the seating mock to their preferred position. A 5-minute practice trial was given to drive freely in a straight and curved road in order for the participants to get familiar with the simulator and the software. Scenarios were provided through a 3 channel simulator and participants were instructed to follow the autonomous vehicle's instructions. They were only allowed to take over control at the limitation scenarios when necessary. The presentation order for capability and limitation scenarios in medium presentation is counterbalanced with half presenting capability scenarios first and half presenting limitation scenarios first. The order within the capability and limitation scenarios are randomized using a Latin square design. Trust measurement was conducted after initial text presentation, during medium presentation, and after medium presentation throughout the experimental session. A short-answer question asking about the capabilities and limitations of the autonomous vehicle related to the scenario contents was implemented right after the end of medium presentation followed by a subjective rating(Appendix E, F). Participants were asked to answer another short-answer question asking the situation of the scenarios, the capabilities and limitations of the autonomous vehicle related to the scenario contents, and a trust questionnaire 1 week after the experimental trial through an online survey. Overall description of experimental procedure is shown in Figure 3.3. The procedure and data collection protocol had been approved by the Institutional Review Board of Seoul National University.

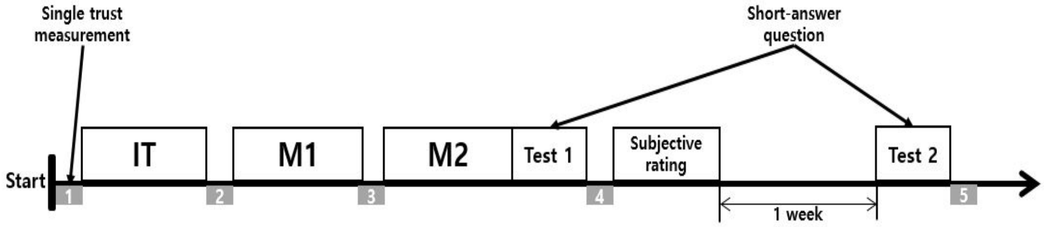


Figure 3.3: Experimental procedure

3.5 Experiment Variables

The independent variables of the study are the type of medium presentation and the presentation order of information. The type of medium presentation has three levels: Text, Video, and Simulator. The presentation order of information has two levels: Limitation-Capability and Capability-Limitation. The dependent variables consisted of three categories. The objective measure of memory and subjective measures of NASA-TLX and trust. Memory measure has three variables: short-answer question score at the end of the experimental session (recall score), short-answer question score 1 week after the experimental session (retention score), and memory retention rate. Short-answer question scores have three measures of capability score (0 to 4), limitation score (0 to 4), and the total score (0 to 8). The total score is the sum of the capability score and limitation score. Short-answer questions were graded whether the participants remembered the key point of autonomous vehicles' behavior and what the driver was supposed to do in response to the event. Memory retention rate was computed as the ratio of retention total score to recall total score. Regarding subjective measures, the ratings of six subscales in the NASA Task Load Index (NASA-TLX) questionnaire and additional scale of understandability of the scenarios were measured with a seven-point scale[11, 12]. Trust was measured through a single-item trust rating (In general, how much do you trust the system in a scale from 0 to 100?) in reference to earlier studies that evaluated automation trust[5, 14, 23]. At the end of each trust measure, participants were required to describe the reason for trust change if a change in trust existed. Two changes of trust due to the trial of the experiment was considered as a dependent measure of trust: a trust change due to exposure to autonomous vehicle product information and trust change due to time lapse. A trust change due to exposure to autonomous vehicle product information was defined as a difference between the trust level after medium presentation and initial trust level. A trust change due to time lapse was defined as a gap between trust level one week after the experimental session and trust level after medium presentation. Trust change during medium presentation was separated into two parts each representing the change due to capability scenarios and limitation scenarios. Trust change construct is shown in Figure 3.4.

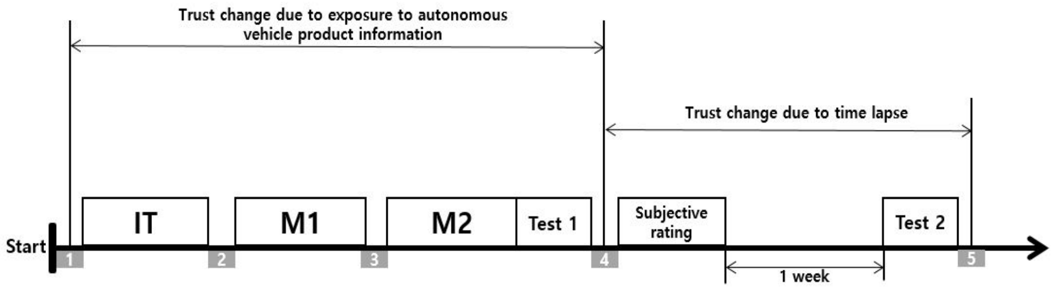


Figure 3.4: Trust change measures and related constructs

3.6 Apparatus

Text instructions for trial one were given in a written paper form. For the text and video instructions in trial two, contents were given on a fifteen inch laptop in a PowerPoint presentation format. For the simulator instructions, the contents for trial two were presented in a static driving simulator with three visual channels, each projecting the front and side visibility. All of the channels have a resolution of 1920 * 1080 pixels and with 42-inch screen size and rendered at 60Hz. The channels were provided with 183.6 degrees of forward Field of view angle for a realistic driving environment. The virtual driving scenarios were designed using the software (UC-win / Road ver.10, Forum8). All questionnaires during the experiment were collected through an online survey with a laptop.

3.7 Statistical Analysis

A chi-square test of homogeneity was conducted to the memory recall score and retention score to test the effect of medium and presentation order of information. The null hypothesis for the effect of medium and presentation order of information on memory recall score are showing no difference between recall scores in medium types and presentation order of information. The null hypothesis for the effect of medium and presentation order of information on memory retention score are showing no difference between retention scores in medium types and presentation order of information. A two-way ANOVA was conducted to the memory retention rate to test the effect of medium and presentation order of information. The null hypothesis for the effect of medium and presentation order of information on retention rate are showing no difference between retention rates in medium types and presentation order of information. The main effect of medium and presentation order of information was verified through post-hoc analysis using Bonferroni multiple pairwise comparisons. If there is a significant interaction effect of presentation order and medium, a simple effect post hoc test was applied.

A two-way ANOVA was conducted to each of the subscales in NASA-TLX, understandability to test the effect of medium and presentation order of information. The null hypothesis for the effect of medium and presentation order of information on subjective workload are showing no difference between each subscale in medium types and presentation order of information. The main effect of medium and presentation order of information was verified through post-hoc analysis using Bonferroni multiple pairwise comparisons. If there is a significant interaction effect of presentation order and medium, a simple effect post hoc test was applied.

Paired t-test was conducted to identify the effect of medium type in exposure to autonomous vehicle product information. The trend of trust fluctuations in each medium was compared and analyzed. A two-way ANOVA was conducted to trust changes to test the effect of medium and presentation order of information. The null hypothesis for the effect of medium and presentation order of information on trust changes are showing no difference between trust changes in medium types and presentation order of information. The main effect of medium and presentation order of information was verified through post-hoc analysis using Bonferroni multiple pairwise comparisons. If there is a significant interaction effect of presentation order and medium, a simple effect post hoc test was applied.

Additional analysis of one-way ANOVA was conducted to trust changes to test the effect of capability and limitation scenarios in medium presentation. The main effect of capability and limitation scenarios in medium presentation was verified through post-hoc analysis using Bonferroni multiple pairwise comparisons. All statistical tests were conducted at a significant level of 0.05 using SPSS 25.

Chapter 4

Results

4.1 Comparison of Medium and Presentation Order in Memory

For recall scores and retention scores, the mean and standard deviation values of each medium are presented in Table 4.1.

Table 4.1: Mean, standard deviation, count, minimum, maximum values of recall and retention scores

		Min	Max	Average	S.D
Recall scores	Text	6	8	7.85	0.489
	Video	6	8	7.85	0.489
	Simulator	2	8	7.55	1.356
Retention scores	Text	1	7	4.55	1.572
	Video	2	7	4.9	1.517
	Simulator	0	7	4.95	1.905

4.2 Recall and Retention Score Result

The results of the chi-square test of homogeneity on memory recall score indicated that three mediums, which is, text, video, and simulator failed to reject the null hypothesis showing no significant difference between the medium in recall scores,

$\chi^2(6) = 4.754, p = 0.576$. Also, the result failed to reject the null hypothesis showing no significant difference between the presentation order of information in recall scores, $\chi^2(3) = 3.108, p = 0375$.

The results of the chi-square test of homogeneity on memory retention score indicated that three mediums, which is, text, video, and simulator failed to reject the null hypothesis showing no significant difference between the medium in retention scores, $\chi^2(14) = 10.686, p = 0.711$. Also, the result failed to reject the null hypothesis showing no significant difference between the presentation order of information in retention scores, $\chi^2(7) = 13.359, p = 0.064$.

In terms of memory retention, retention rate result from ANOVA failed to reject the null hypothesis showing that there is no significant difference across medium types, $F(2, 59) = 0.515, p = 0.600$. Also, The presentation order and medium type $\times$ presentation order interaction effects between the two factors was not found which failed to reject the null hypothesis, $F(1, 59) = 0.013, p = 0.909, F(2, 59) = 0.278, p = 0.759$. However, there was a general decline in the retention score compared to the recall score in all three mediums ($M = 2.95, SD = 1.511$).

4.3 NASA-TLX Rating Result

Six subscales and understandability were analyzed through two-way ANOVA and the results are shown in Figure 4.1 and Table 4.2, 4.3.

Among seven scales, the main effect of the medium was found in physical demand, $F(2, 59) = 7.385, p = 0.001$, and temporal demand, $F(2, 59) = 5.617, p = 0.040$, supporting the alternative hypothesis indicating a difference in physical demand and temporal demand among medium types. A post-hoc analysis showed significantly higher physical demand in the simulator than text and video and higher temporal demand in the simulator than video (Table 4.2,Figure 4.1).

Table 4.2: Means and standard deviations and inter-group mean differences of NASA-TLX subscales for each medium type

	Text Group	Video Group	Simulator Group	P Value	Mean difference (Pairwise comparison p value)		
					Video Text	Simulator Video	Simulator Text
Mental demand	2.85	2.45	3.20	0.202	-0.40	0.75	0.35
Physical demand	1.40	1.15	2.30	0.001*	-0.25	1.15* (0.002)	0.90* (0.018)
Temporal demand	1.95	1.30	2.35	0.040*	-0.65	1.05* (0.037)	0.40
Performance	4.10	3.00	3.70	0.204	-1.10	0.70	-0.40
Effort	2.70	2.15	2.75	0.240	-0.55	0.60	0.05
Frustration	2.30	1.50	2.35	0.053	-0.80	0.85	0.05
Understandability	2.15	2.30	1.50	0.184	0.15	-0.80	-0.65

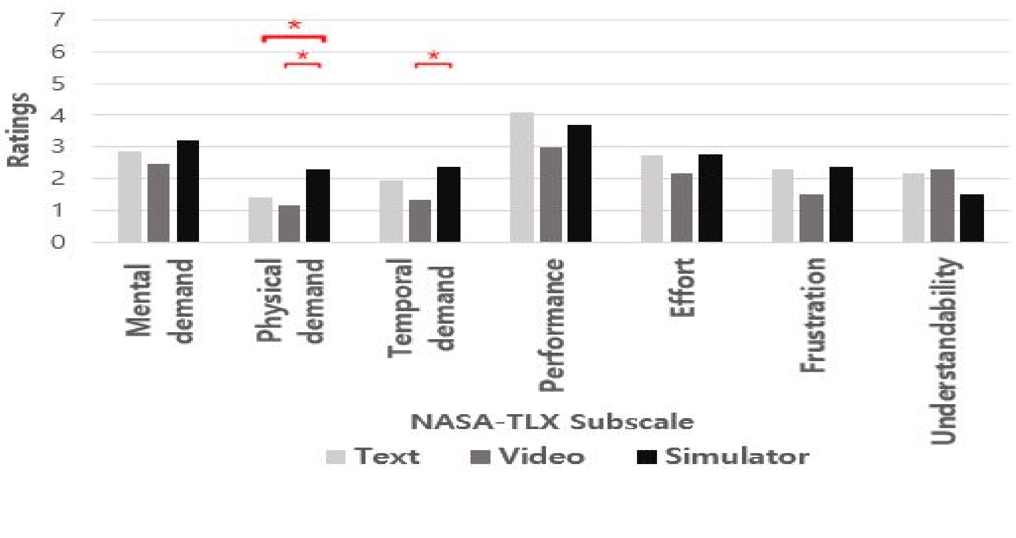


Figure 4.1: Mean ratings of NASA-TLX subscales for each medium type with asterisk indicating significance in the multiple pairwise comparisons

Additionally, the main effect of presentation order of information was found in frustration, $F(1, 59) = 14.017, p = 0.003$. Comparing the average, showing the limitation prior to capability showed significantly higher frustration compared to capability prior presentation order (Table 4.3, Figure 4.2).

Table 4.3: Means and standard deviations and inter-group mean differences of NASA-TLX subscales for each information presentation order

	Capability Prior	Limitation Prior	P Value	Mean difference (Capability Prior - Limitation Prior)
Mental demand	2.60	3.07	0.173	-0.47
Physical demand	1.43	1.80	0.159	-0.37
Temporal demand	1.73	2.00	0.424	-0.27
Performance	3.83	3.37	0.357	0.46
Effort	2.30	2.77	0.147	-0.47
Frustration	1.57	2.53	0.003*	-0.96
Understandability	2.13	1.83	0.423	0.30

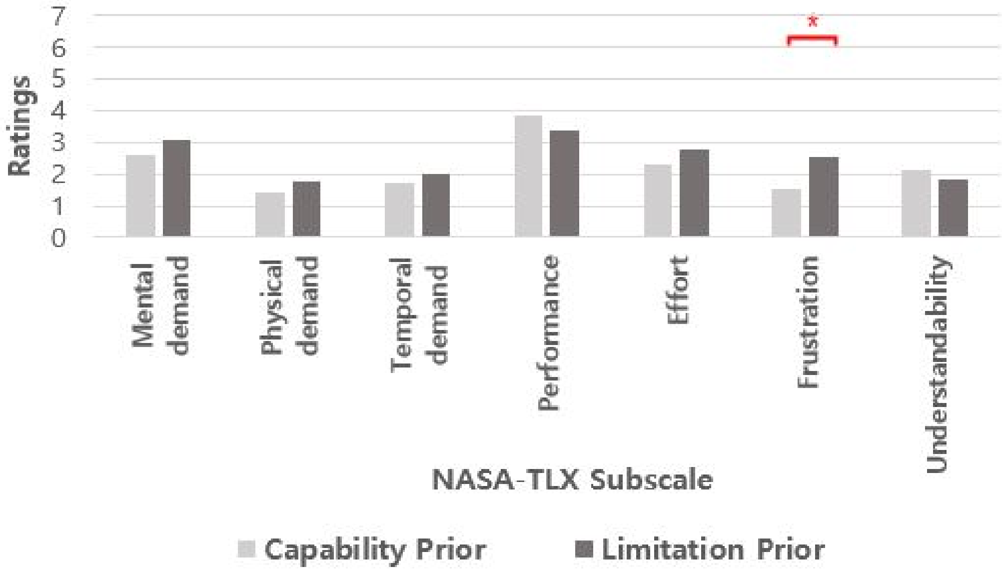


Figure 4.2: Mean ratings of NASA-TLX subscales for each presentation order with asterisk indicating significance in the multiple pairwise comparisons

An interaction effect of medium and presentation order of information was found in physical demand, $F(2, 59) = 4.017, p = 0.023$. A simple effect post-hoc test was conducted for medium types and presentation order of information and showed higher physical demand when limitation information was presented prior to capability information in simulator situation (Figure 4.2). Other interactions were not founded to be significant in physical demand.

The main effect of medium and presentation order of information and interaction effect were not found in mental demand, performance, and understandability.

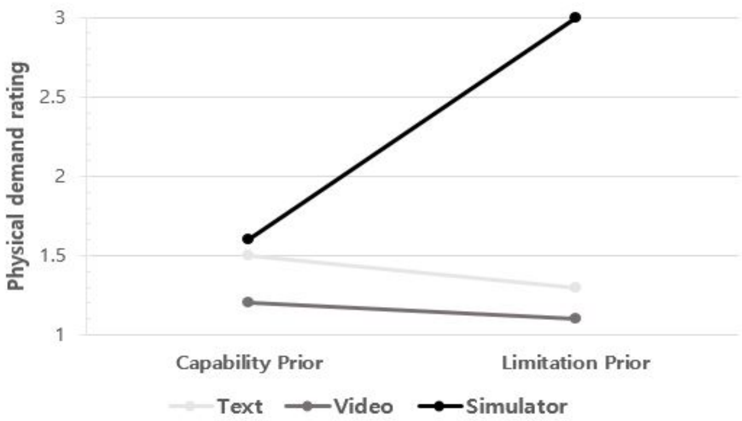


Figure 4.3: Mean ratings of physical demand for each medium type and information presentation order

4.4 Trust Rating Result

Paired t-test result of trust in each medium has shown that for each of the medium supporting the alternative hypothesis and rejecting the null hypothesis. There was a significant difference between initial trust level and trust level after the medium presentation has ended ($Text : t(19) = -3.208, p = 0.005; Video : t(19) = -2.318, p = 0.032; Simulator : t(19) = -4.097, p = 0.001$). Each group showed an increase in trust level ($Text : M = 7.50, SD = 10.455; Video : M = 11.15, SD = 21.512; Simulator : M = 17.05, SD = 18.611$).

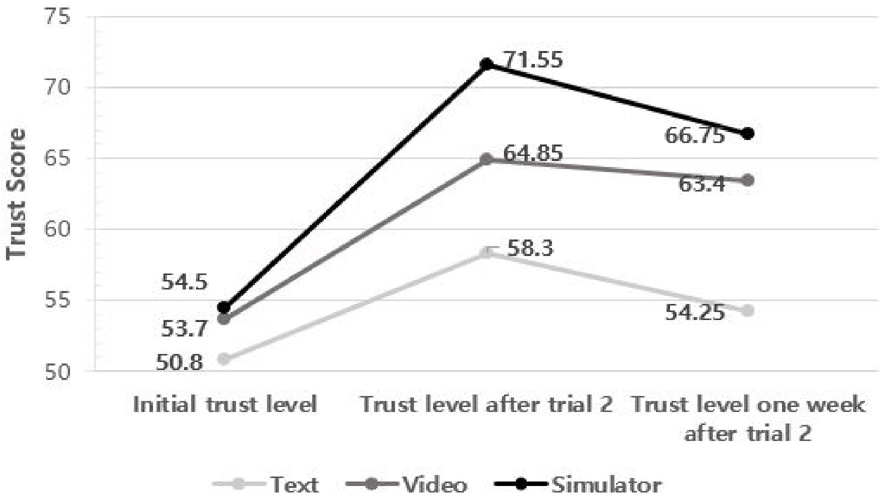


Figure 4.4: Mean trust score of initial trust, trust level after medium presentation and trust level one week after medium presentation for each medium type

Results from two-way ANOVA analyzing trust changes from medium presentation and time lapse indicated that there was no significant trust change difference between mediums resulting from medium presentation and failed to reject the null hypothesis. The main effect of the presentation order of information and interaction effect were not found in the trust change result from medium presentation . Moreover, main effect of medium and presentation order of information and interaction effect were not found in trust changes due to time lapse.

Additional analysis of presentation order separating the effect of capability and limitation showed a significance difference between text and simulator in a limitation scenarios, $F(1, 59) = 5.064, p = 0.009$.

A total of 121 descriptions were submitted through an online survey explaining the reason for trust change. A detailed number of the description is shown in table 4.4. The reason for the rise and fall of trust is mainly from the view of an autonomous vehicle function. Other reasons that influenced trust are from the difference of medium during trials, memory loss, and limitation scenarios.

Table 4.4: Detail number of online survey subjective descriptions

		Increase				Decrease				
	Overall	Medium	Memory	System function limitation	Other	Medium	Memory	System function limitation	Other	No change
Text	41	0	0	9	4	1	0	0	8	19
Video	49	8	2	5	16	0	1	2	5	10
Simulator	31	5	0	4	7	0	2	0	1	12
Total	121	13	2	18	27	1	3	2	14	41

Chapter 5

Discussion

This study aimed to compare the effects of medium and presentation order of information on memory recall, memory retention, and automation trust. The study also investigated how each medium and presentation order of information affects workload through subjective ratings. In the aspect of memory, no significant difference was found between medium types. The workload result demonstrated that the simulator was less effective in physical, temporal demand, and frustration compared to the other two medium types. Lastly, trust increased in the simulator situation when the limitation scenarios were presented compared to text situation.

5.1 Findings and Interpretations

Based on the results of memory recall and retention (Table 4.1), the general decline of retention score for each medium can be described through memory decay theory[4]. Memory decay theory explains the fading effect of memories which represents forgetting of information. Regardless of medium type, memory decay occurred and this result can suggest that in order to retain the obtained information, delivery of information should be repeated to alleviate the memory fading effect.

Based on the results, there was no difference between medium in terms of memory recall (Table 4.1). This coincides with the result of related studies insisting that medium only delivers the information and does not affect educational performance. The result of memory retention, however, indicates that the recall process after a significant amount of time does not differ depending on the medium type. This result interprets that different encoding process of each medium may not affect education and memory performance.

The result with subjective measurements using NASA-TLX clearly shows that simulator applies higher temporal demand compared to video and higher physical demand compared to video and text. Simulator group was instructed to interfere and drive in situations where the autonomous system requests the driver to do so. Physical demand may have resulted from the physical activity of direct intervention experience and temporal demand, from the pressure of driving activity. This possibility of intervention can also be the reason to higher physical demand when presenting limitation scenarios prior to capability scenarios in a simulator group and higher frustration when limitation scenarios were presented prior to capability scenarios. Since intervention experience in the simulator is given only in limitation scenarios, participants tend to expect that they may have to intervene even in a capability scenario. This causes additional tension to the body, resulting in higher physical demand. Showing higher frustration with limitations presented first may be explained with a confirmation bias of limitation information. Participants who experienced the limitation information first may have been influenced by the limitation scenarios and tend to proceed with the trials with a biased perception of the autonomous vehicles leading to increased frustration.

In terms of automation trust, effects from mediums in trials were confirmed from paired t-test. The result shows that there was a general increase in trust in all medium types. The description of reason to trust change stated by the participants indicated that the information of autonomous vehicles given from exposure to autonomous vehicle product information has provided stability and reliability. 35 out of 60 descriptions of trust increase resulting from general information of the autonomous vehicle and limitation scenarios support the fact that the information of autonomous vehicle product from each medium provides stability and reliability.

Trust change comparisons in medium types did not show a significant difference. However, further analysis of the effect from capability and limitation scenarios showed that there is a difference between simulator and text from medium presentation in the limitation scenarios. This can be interpreted that simulator showed significantly higher trust change only in a limitation scenarios. Moreover, the result in figure 4.2 shows that an incremental change in trust has occurred due to exposure to autonomous vehicle product information. Based on the statement from the participants' descriptions of the reason for trust change, the information of the autonomous vehicle in limitation scenarios provided prior knowledge of how the system will react and what situations could happen. Also, direct experience in the simulator group played a crucial role in giving participants how to act in takeover situations. This result coincides with past studies that show prior experience to takeover situations increased overall trust in automation[10]. Also, it can be conjectured that if limitation scenarios of intervention such as warning or takeover contain only functional limitations without failure, it could lead to an increase in trust level.

5.2 Implications

The result of memory recall and retention suggest that repetitive educations are needed regardless of medium type in order to alleviate fading effect of memory. Also, since there is no significant difference between mediums in recall and retention performance, considering the selection of medium in education seems not necessary.

The NASA-TLX ratings suggest that the selection of simulator in education can cause higher physical demand compared to video and text, and higher temporal demand compared to the video. Higher physical demand should be considered when selecting simulator over other medium types and enough time should be given when choosing simulator over video materials. Additionally, result that shows higher frustration when limitation scenarios are given prior to capability scenarios suggests that if possible, capability scenarios should be presented before limitation scenarios in order to reduce frustration level.

The result of trust change did not show significant difference between mediums, it verifies that limitation information of autonomous vehicle presented in the simulator have greater effects on trust compared to information presented in the text. Theoretically, in the domain of autonomous vehicles, the result proves that the difference in modality between the types of medium affects the trust level restricted in a functional limitation scenario. This can also be interpreted that direct experience from a simulator can express intervention information clearly. Synthetically, if functional limitation does not contain an automation failure, presenting the information through a simulator can increase trust. This can benefit by reducing the disuse of the automation system that allows many people to encounter the system.

An implication can be drawn from the results of memory performance and trust change. A memory loss due to time lapse has been discovered along with a trust decrease. This trend may lead to a conjecture that fading process of memory and a decrease in trust level develops simultaneously and a positive correlation between memory and trust exists.

Summing up the implications, 5 design recommendations can be drawn from this study.

- If contents are identical, selection between text, video, and the simulator should rely on the aspect of affordable, accessible and efficient type of medium.
- In terms of workload, using other media besides simulator can reduce the physical demand.
- Presenting limitation information prior to capability information can reduce frustration in all medium types and physical demand in simulator.
- Additional spare time can reduce temporal demand in simulator compared to video material.
- If the accuracy of warning intervention is precise or automation failure is evitable, education of system's functional limitation through simulator is recommended to increase trust.

The above 5 recommendations should be considered carefully depending on the purpose of using a simulator for educating autonomous vehicle descriptions.

This study has two limitations. The amount of time given to identify the retention effect was limited to 1 week. A significant difference between medium types can be identified when a longer time than a week is given to the participants. Also, the scenarios representing the capability and limitation information of autonomous vehicles are based on ideal situations with only functional limitations.

Future studies should focus on investigating the long-term effects of medium types on educational memory performance verifying the difference between three mediums. Additional mediums with higher immersion such as virtual reality should be included in the comparison of medium types to identify the effect. Moreover, modifying the ratio and the scenarios of the capability and limitation should be considered in order to cover various situations. Finally, presenting realistic situations by including automation failure and accidents along with uncertainty must be studied in order to analyze automation trust and memory performance.

Based on the experimental results, this study can contribute to providing the guideline in selecting appropriate medium type depending on the purpose of education and reduce the possibility of misuse and disuse by working as a guidance in identifying appropriate level of calibrated trust, thus trust change resulting from various medium types, leading to increased safety.

Chapter 6

Conclusions

This study has investigated the effect of medium type and presentation order on memory, subjective workload rating and trust. It has been identified that there was a significant difference in trust in a limited situation and subjective workload rating, but no difference in terms of memory performance. As a result, 5 design recommendations have been established when education of autonomous vehicle product information is considered.

Appendices

A Driving Technology of Market Released Autonomous Vehicles

	Manufacturer	Model	System name
1	Volkswagen	ID4	Iqdrive
2	Gm Motors Cadillac	CT6	Super cruise
3	Tesla	model 3	Autopilot
4	Ford	Explorer	Co-Pilot360
5	Honda	HR-V	Honda Sensing
6	Hyundai	Palisade	SmartSense

	Manufacturer	Lane Keeping Assist System (LKAS)	Front Collision-Avoidance Assist (FCA)	Adaptive Cruise Control (ACC)
1	Volkswagen	Lane Assist Lane Keeping System	Front Assist Autonomous Emergency Braking	Adaptive Cruise Control
2	Gm Motors Cadillac	Lane Centering Lane Keep Assist	Front Collision Alert Automatic Emergency Braking	Adaptive Cruise Control
3	Tesla	Lane Assist Lane Departure Avoidance	Collision Avoidance Assist Automatic Emergency Braking	Trafic Aware Cruise Control
4	Ford	Lane Keeping System	Automatic Emergency Braking	
5	Honda	Lane Keeping Assist System	Collision Mitigation Braking System	Adaptive Cruise Control
6	Hyundai	Lane Following Assist Lane Keeping Assist	Forward Collision-Avoidance Assist	Smart Cruise Control

B Text instruction: Initial text presentation

C1. 이번 시나리오는 같은 차선에서 앞에 본인의 차보다 느리게 주행 중인 차량이 있을 때 자율주행이 어떻게 하는지 보여주는 상황입니다.

- 주행 중 앞에 느리게 가는 차량이 있어 주행에 방해가 된다면 좌, 우 차선의 상황에 따라 자율주행 차량이 자동적으로 차선 변경을 한 뒤 느리게 주행하는 차량을 추월함

C2. 이번 시나리오는 옆 차선에서 주행 중이던 차량이 급하게 앞으로 끼어들었을 때 자율주행이 어떻게 하는지 보여주는 상황입니다.

- 옆 차선에서 주행 중이던 차량이 갑자기 앞으로 끼어들 경우 자율주행 차량은 자동적으로 급제동을 하여 충돌을 방지함

C3. 이번 시나리오는 시내에서 주행 중에 앞 사거리에서 신호등의 신호가 빨간색일 때 이후에 자율주행이 어떻게 하는지 보여주는 상황입니다.

- 사거리에서 신호등의 신호가 빨간색일 경우 정지하였다가 신호등의 신호가 초록색으로 바뀔 경우 다시 주행 시작함

C4. 이번 시나리오는 고속도로에서 진출로로 빠져나가야할 때 자율주행이 어떻게 하는지 보여주는 상황입니다.

- 목적지에 따라 고속도로에서 진출로로 빠져나가야할 경우 자율 주행 차량이 자동적으로 진출 차선으로 차선을 변경 후 진출로로 주행함

L1. 이번 시나리오는 앞에 차선 표시선이 누락된 구간이 있을 때 자율주행이 어떻게 하는지 보여주는 상황입니다.

- 앞에 차선 표시선이 누락된 구간이 있을 경우 약 8초 전에 제어권 전환 요청을 한 뒤 'Drive now(운전하세요)' 라는 문구와 함께 운전자에게 운전 권한을 넘김

L2. 이번 시나리오는 앞에 도로가 손상되어 라바콘으로 공사를 알리는 구간이 있을 때 자율주행이 어떻게 하는지 보여주는 상황입니다.

- 앞에 라바콘이 배치되어 있고 공사 구간이 있을 경우 자율주행 시스템이 약 8초 전에 제어권 전환 요청을 한 뒤 'Drive now(운전하세요)' 라는 문구와 함께 운전자에게 운전 권한을 넘김

L3. 이번 시나리오는 앞에 굽은 도로에서 차선 표시선이 누락된 구간이 있을 때 자율주행이 어떻게 하는지 보여주는 상황입니다.

- 앞에 굽은 도로에서 차선 표시선이 누락된 구간이 있을 경우 약 8초 전에 제어권 전환 요청을 한 뒤 'Drive now(운전하세요)' 라는 문구와 함께 운전자에게 운전 권한을 넘김

L4. 이번 시나리오는 비가 점점 심하게 오면서 도로 표면에 물기가 많아질 때 자율주행이 어떻게 하는지 보여주는 상황입니다.

- 비가 오기 시작하여 도로에 물기가 많아질 경우 자율주행 시스템이 제어권 전환 요청을 한 뒤 'Drive now(운전하세요)' 라는 문구와 함께 운전자에게 운전 권한을 넘김

C Text instruction: Medium presentation

시나리오 1

- 주행 중 앞에 느리게 가는 차량이 있어 주행에 방해가 된다면 좌, 우 차선의 상황에 따라 자율주행 차량이 자동적으로 차선 변경을 한 뒤 느리게 주행하는 차량을 추월함

시나리오 2

- 옆 차선에서 주행 중이던 차량이 갑자기 앞으로 끼어들 경우 자율주행 차량은 자동적으로 급제동을 하여 충돌을 방지함

시나리오 3

- 사거리에서 신호등의 신호가 빨간색일 경우 정지하였다가 신호등의 신호가 초록색으로 바뀔 경우 다시 주행 시작함

시나리오 4

- 목적지에 따라 고속도로에서 진출로로 빠져나가야할 경우 자율주행 차량이 자동적으로 진출 차선으로 차선을 변경 후 진출로로 주행함

시나리오 5

- 앞에 차선 표시선이 누락된 구간이 있을 경우 약 8초 전에 제어권 전환 요청을 한 뒤 'Drive now(운전하세요)' 라는 문구와 함께 운전자에게 운전 권한을 넘김

시나리오 6

- 앞에 라바콘이 배치되어 있고 공사 구간이 있을 경우 자율주행 시스템이 약 8초 전에 제어권 전환 요청을 한 뒤 'Drive now(운전하세요)' 라는 문구와 함께 운전자에게 운전 권한을 넘김

시나리오 7

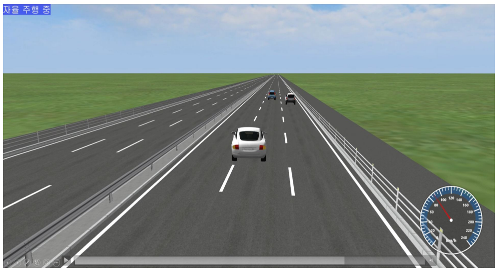
- 앞에 굽은 도로에서 차선 표시선이 누락된 구간이 있을 경우 약 8초 전에 제어권 전환 요청을 한 뒤 'Drive now(운전하세요)' 라는 문구와 함께 운전자에게 운전 권한을 넘김

시나리오 8

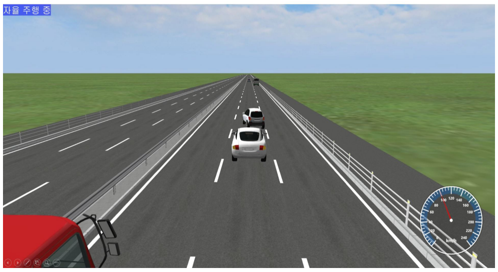
- 비가 오기 시작하여 도로에 물기가 많아질 경우 자율주행 시스템이 제어권 전환 요청을 한 뒤 'Drive now(운전하세요)' 라는 문구와 함께 운전자에게 운전 권한을 넘김

D Video instruction: Medium presentation

C1

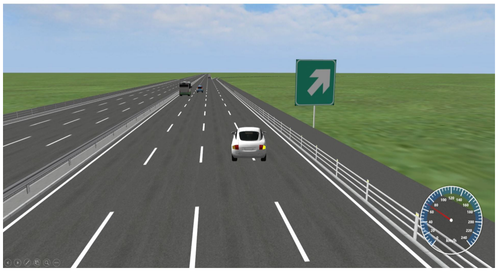


C2



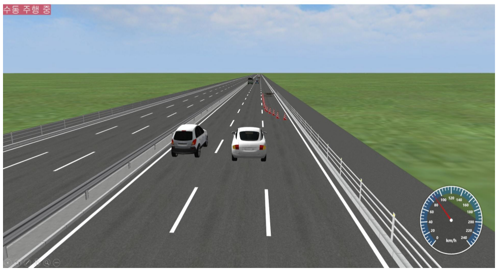
C3

C4



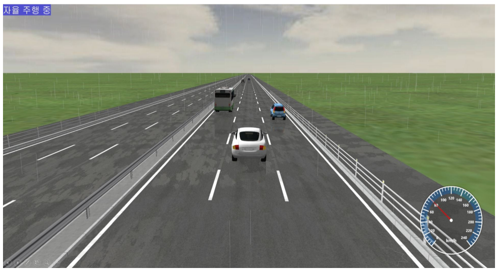
L1

L2



L3

L4



E Short answer question

참여하셨던 실험에서 기억나시는 것을 모두 상세히 말씀하시면 됩니다. 모든 상황은 자율주행 차량을 탑승하고 있다고 가정하고 있습니다. 답변은 주어진 상황에서 다음에 어떤 일이 벌어질지 자율주행 차량의 시점에서, 그리고 운전자 시점에서 서술해 주시면 됩니다.

질문 ex. 주행 중에 앞에 사람이 무단횡단을 시도하고 있습니다. 이 이후에 어떤 상황이 벌어질지 서술하시오.

답변 ex1. 운전자의 개입 없이도 자율주행 차량이 알아서 인식하고 급제동 하였다.

답변 ex2. 자율주행 차량이 멈추지 않아 사람과 접촉사고가 일어났다.

답변 ex3. 자율주행 차량이 사람을 인식하였지만 운전자가 직접 브레이크를 밟아 멈추었다.

1. 차량들과 함께 고속도로에서 주행 중인 상황입니다. 같은 차선에서 앞에 본인의 차보다 느리게 주행 중인 차량이 있습니다. 이 이후에 어떤 상황이 벌어질지 서술하시오.

2. 차량들과 함께 고속도로에서 주행 중인 상황입니다. 옆 차선에서 주행 중이던 차량이 급하게 앞으로 끼어들었습니다. 이 이후에 어떤 상황이 벌어질지 서술하시오.

3. 시내에서 주행 중인 상황입니다. 앞에 사거리에서 신호등의 신호가 빨간색입니다. 이 이후에 신호등이 초록색으로 바뀔 때까지 어떤 상황이 벌어질지 서술하시오.

4. 차량들과 함께 고속도로에서 주행 중인 상황입니다. 고속도로에서 차선을 변경하여 진출로로 빠져나가야 합니다. 이 이후에 어떤 상황이 벌어질지 서술하시오.

5. 차량들과 함께 고속도로에서 주행 중인 상황입니다. 앞에 차선 표시선이 누락된

구간이 있습니다 . 이 이후에 어떤 상황이 벌어질지 서술하시오.

6. 차량들과 함께 고속도로에서 주행 중인 상황입니다. 앞에 도로가 손상되어 라바콘으로 공사를 알리는 구간이 있습니다 . 이 이후에 어떤 상황이 벌어질지 서술하시오.

7. 차량들과 함께 고속도로에서 주행 중인 상황입니다. 앞에 굽은 도로에서 차선 표시선이 누락된 구간이 있습니다 . 이 이후에 어떤 상황이 벌어질지 서술하시오.

8. 차량들과 함께 고속도로에서 주행 중인 상황입니다. 비가 점점 심하게 오면서 도로 표면에 물기가 많아졌습니다. 이 이후에 어떤 상황이 벌어질지 서술하시오.

F Subjective workload measure

정신적 부하 (Mental demand)

- 얼마나 정신적인 활동이 요구되었습니까?

육체적 부하 (Physical demand)

- 얼마나 육체적인 활동이 요구되었습니까?

시간적 압박 (Temporal demand)

- 얼마나 시간적인 압박을 느꼈습니까?

수행도 (Performance)

- 얼마나 성공적으로 잘 수행하였다고 생각하십니까?

노력 (Effort)

- 얼마나 정신적/육체적으로 노력을 해야 했습니까?

스트레스 (Frustration)

- 얼마나 혼란, 짜증, 압박, 불안과 같은 감정을 느꼈습니까?

이해도 (Understandability)

- 시나리오가 이해하기에 얼마나 어려웠습니까?

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국문초록

본 논문에서는 자율주행차량 제품의 정보를 사용자에게 전달하는데 있어 기억지속, 교육부하와 자동화에 대한 신뢰 측면에서 향상시킬 수 있는 방안을 고려한다. 본 연구에서는 문제에 대한 답을 찾기 위하여 다양한 매체 종류와 정보 제공 순서를 비교한다. 그 결과 본 논문에서는 자율주행차량 제품에 대한 교육을 실시하는데 있어 필요한 교자재를 어떻게 설계하고 구성해야하는지 방향을 제공하는 가이드라인을 제시하고 사용자와 자동화 시스템 사이의 적절한 신뢰 수준을 찾는데 유용한 정보를 제공한다.

주요어: 자율주행, 자동화에 대한 신뢰, 정보 전달

학번: 2019-26296