Understanding Driver's Situation Awareness in Highly Automated Driving

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Summary

Research goal

To investigate the influence of road complexity and lead time on driver's situation awareness in highly automated driving.

Data collection

Seven participants were recruited to the study. Three consecutive experiments with video-based stimuli were conducted in the lab environment.

Independent variables

Study 1: Road complexity, lead time

Study 2 & 3: Traffic density, road type

Dependent variables

Study 1: SAGAT, SART, readiness to drive

Study 2 & 3: SAGAT, SART, perceived safety, subjective pressure, response time

Main findings

Driver's situation awareness is influenced by road complexity, but minimal effects of lead time. When the road complexity divided into two factors, which were traffic density and road type, only traffic density affect's drivers' situation awareness. Also, one interesting result was that drivers seem to adjust their situation awareness level according to the contexts.

Introduction

SAE level 3 is defined as a vehicle that is highly automated where drivers are not required to do any driving performance during the automated driving and **only intervene when the system request the drivers to assume control of the driving task**. This conditionally automated vehicle enables **drivers to be engaged in a non-driving related task (NDRT)** during the automated driving which influences when reassuming control of the vehicle.

Situation awareness (SA) is defined as **'the perception of the environment in the current situation, the comprehension of the current situation, and the projection of future status.'** During driving, SA plays an important role as drivers are required to gather information from the environment to understand the current situation and be able to decide and act on rapidly changing events. Especially, in level 3 automation, SA will play a critical part during the transition of control between the vehicle and the drivers. Takeover (TO) and SA are strongly linked in highly automated driving situations where drivers' level of SA decreases during automated driving due to the possibility of drivers being involved in NDRT and therefore influencing drivers' SA during the takeover process. **This suggests that a level 3 automated vehicle requires drivers to regain a certain level of SA during a certain amount of time to be able to regain control of the vehicle.**

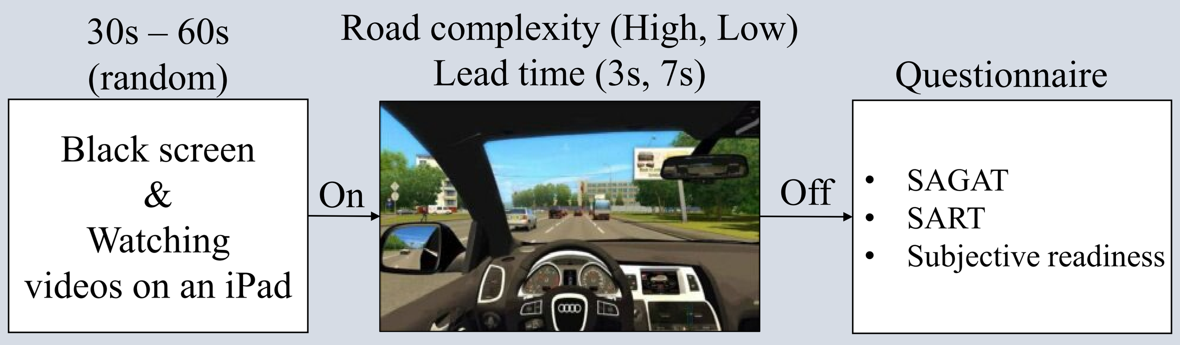
In this research, **we investigate how drivers' SA is affected by different road situations when a takeover request (TOR) is issued during highly automated driving.** Road complexity was considered a critical factor during the perception of information. Visual perception of information will depend on the amount, variability, and complexity of visual distractors given to drivers. Therefore, the present study investigates the effect of road complexity on SA after a takeover request in highly automated driving.

Experiment 1

In the first experiment, we investigated the **effects of road complexity (high, low) and lead time (3s, 7s)** on the driver's situation awareness.

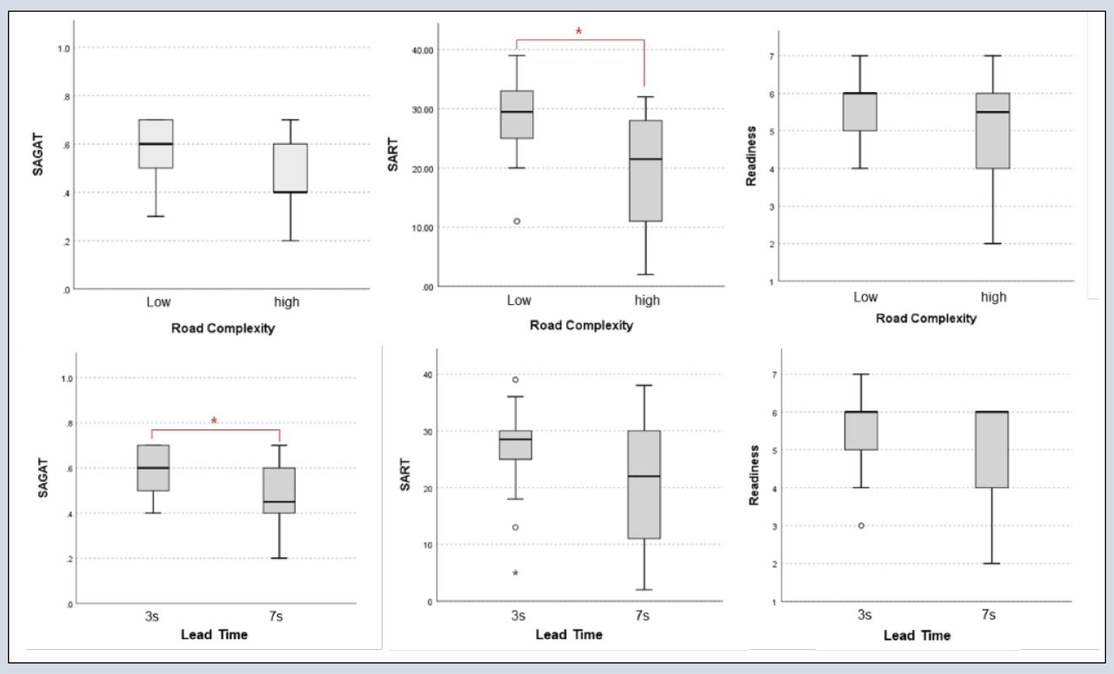
As an objective measure to collect driver's situation awareness, **SAGAT questionnaire including 10 items were developed.** SAGAT measures the situation awareness by three levels. SA level 1 measures driver's current level of perception on the situation. Four items were used to measure the SA level 1 such as *"how may lanes were on the road?"*. SA level 2 measures driver's comprehension on the situation. Four items were used to measure SA level 2 such as *"How was the distance between the ego-vehicle and the car in front of you changed?"*. Lastly, SA level 3 measures driver's projection of the situation. Two items were used to measure SA level 3 such as *"How should I change the speed of the car?"*.

As a subjective measure to collect driver's situation awareness, **SART questionnaire consisting of 10 items was used.** SART measures three dimensions of SA, the attentional demand, attentional supply and understanding. Lastly, we measured **driver's subjective readiness to drive** with a single-item questionnaire.



Procedure of the first experiment

Experiment was conducted in the lab environment. A 27 inches monitor was used to provide driving stimuli. A tablet PC was used for providing the NDRT, and it was located at the right side of the monitor. At the beginning of each trial, the monitor showed an empty screen. Between 30s and 60s after each trial started, one of the stimuli videos was presented on the monitor with 1s of beep sound. After the stimulus turned off, participants were asked to complete questionnaires on SA and subjective readiness to drive. This procedure was iterated for four times with two levels of road complexity (high, low) and lead time (3s, 7s).



Boxplot of the first experiment's results

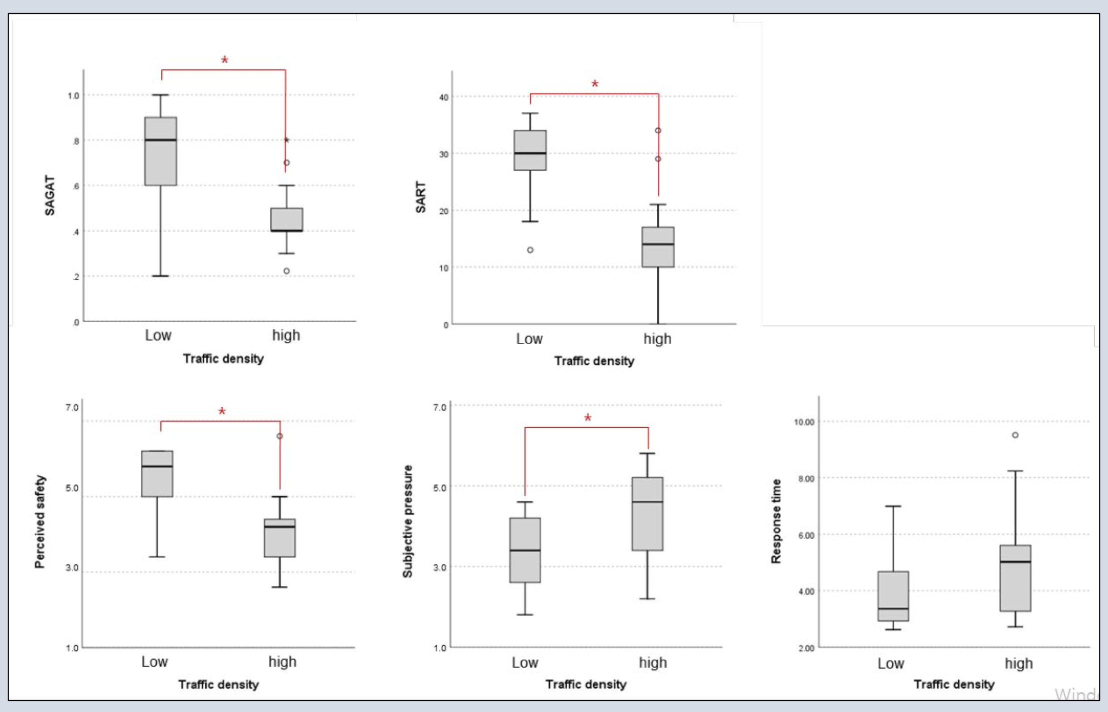
Mann-Whitney U test was used to analyze the data. The results of the first experiment indicated that there was significant main effect of road complexity on the SART score of drivers. The participants' subjective SA level was higher in the low complexity conditions compared to the high complexity conditions($p=0.19$). There was no difference in SAGAT and subjective readiness between the road complexity condition. There was a significant difference in SAGAT score between the lead time condition. The SAGAT score was higher in 3s of lead time compared to the 7s($p=0.31$). No significant differences were found in SART and readiness between the lead time conditions.

Experiment 2

In the second experiment, videos with 60s length were provided to the participants. That is, unlike the first experiment, participants could see the video as much as they wanted. Participants were asked to push the enter key when they think they acquired enough information to start the drive. Driver's situation awareness was measured in the second experiment by SAGAT and SART. In addition, **perceived safety of the situation, subjective pressure, and response time** were measured.

Procedure of the second experiment

The results of second experiments showed that the objective and subjective level of situation awareness were differed by traffic density. SAGAT and SART score was significantly low in the high traffic condition ($p=0.001$; $p<0.001$). Also, participants felt less safe, higher pressure in high traffic condition($p=0.03$; $p=0.013$). However, there was no statistical differences in response time between different level of traffic density($p=0.211$).

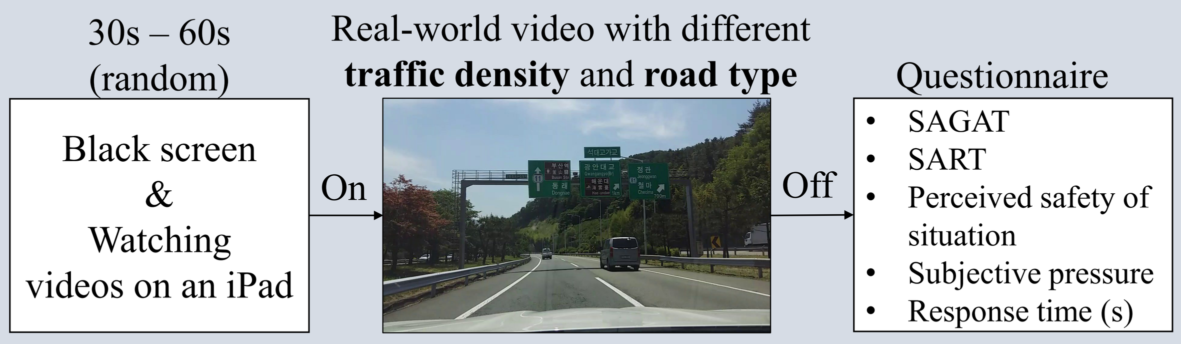


Boxplot of the second experiment's results

In terms of the road types, we could not find the main effects of road type on the driver's SA level, subjective pressure, perceived safety and response time in the second experiment.

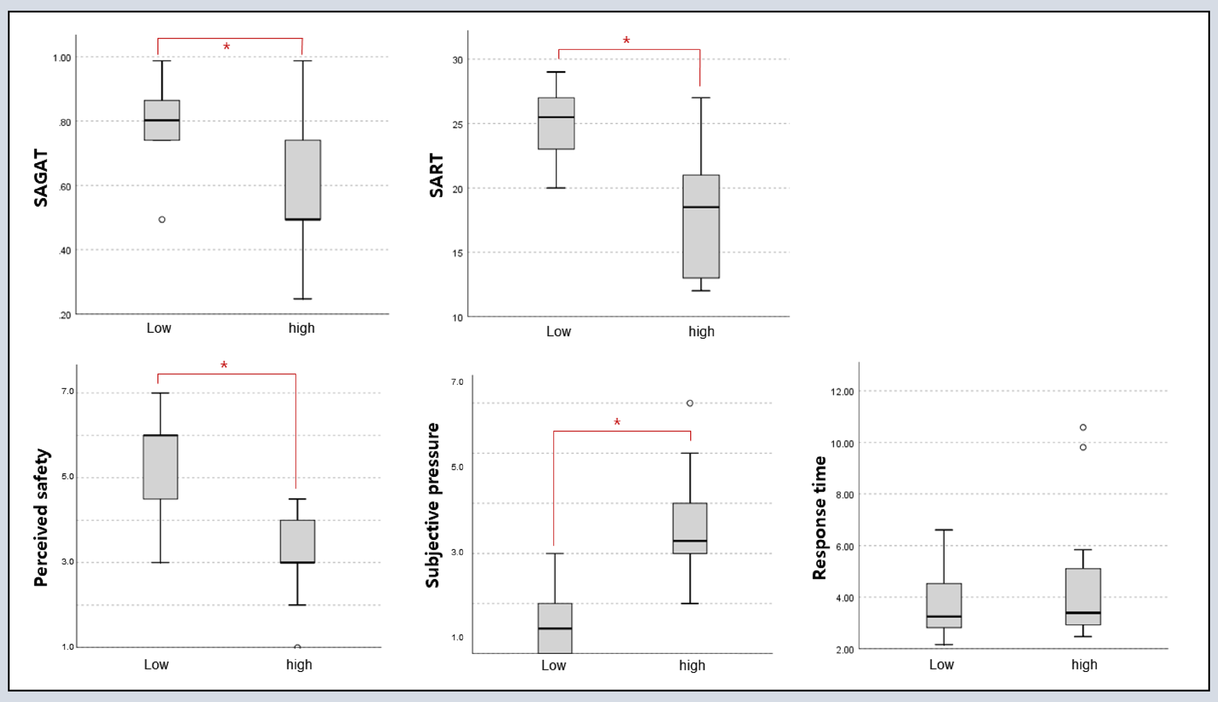
Experiment 3

In the third experiment, we investigated whether the results of the second experiment are reproduced with the real-world information. The procedure was identical to the second experiment, however, stimuli from real-world video were presented to the participants.



Procedure of the third experiment

The results of third experiment also revealed the main effects of traffic density on the driver's SA, perceived safety, and subjective pressure. The objective situation awareness level, measure by SAGAT, was higher in the low traffic condition compared to the high traffic condition ($p=0.02$). In addition, the SART score was also greater in the low traffic condition ($p<0.001$). There were significant differences in the perceived safety and subjective pressure, where participants felt more safer ($p<0.001$) and less pressure ($p<0.001$) in low traffic condition. However, the response time had no difference between two conditions ($p=0.481$).



Boxplot of the third experiment's results

Discussion & future works

In the first experiment, we investigated the effects of road complexity and lead time on the SA. As expected, **participants revealed lower level of SA in the high road complexity condition**. However, the lead time did not influence the driver's subjective situation awareness, and even the SAGAT score was low in longer condition. One explanation of this results could be that when the situation becomes much complex, the expected level of full awareness on the situation also increases. Therefore, **people tended to acquire information most relevant to the reengage, rather than gaining all information on the roads.**

In the second and third experiment, we attempted to identify the effects of road complexity by dividing it into road type and traffic factors. Similar results were found in both experiments, **where traffic density had profound effects on SA formation, while environmental had minor effects**. This result suggests the driver's level of situational awareness could be influenced by the characteristics of surrounding vehicles. The subjective responses might support this phenomenon because individual who is under stress and pressure often has difficulty in forming SA accurately and quickly. Therefore, it is important for designing HMIs of self-driving vehicles to intervene drivers where they feel less pressure when recognizing the situation, particularly in situations where there are lots of related surrounding vehicles.

One interesting finding was that **there was no significant difference in RTs between traffic conditions.** Participants pressed the button with lower SA level in high traffic situations. This result might indicate that **people adjust their desired SA level according to the traffic contexts, rather than attempting to achieve a fixed level.** Also, this might influence the TO task, where drivers' reaction to reengage control of the vehicle is highly dependent on their response time, although they do not reach an appropriate level of SA.

From these results, we suggest further research focusing on the relation between response time and SA level. Despite the limitation of the number of participants was small and low feasibility of testing environment, this study contributes to the SA research in highly automated driving.