Eye-Gaze Analysis of HUD Interventions for Conditional Automation to Increase Situation Awareness

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Figure 1: High Fidelity Driving Simulator with Head-up Display Intervention

ABSTRACT
Automated driving seems promising to reduce crashes caused by human error. However, in the transition towards automated driving, a human is still required in some automation levels in some circumstances. Specifically, in conditional automation or SAE Level 3, a human needs to be able to continue the driving task any time the vehicle requests it. This means that throughout the L3 automated driving, this “fallback-ready user” needs to remain in a state to continue driving, even when they are engaged in other tasks, such as watching a movie. We designed three interventions with the aim to increase their fallback-readiness and have tested them in a high-fidelity video driving simulation study. In this video, we present and describe the interventions, the study design and the setup to test the interventions.

CCS CONCEPTS
• Human-centered computing → Usability testing; User studies; Laboratory experiments.

KEYWORDS
Conditional Automated Driving; High Fidelity Simulation; Video Simulation; User Study; Study Design; Eye-Tracking;

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1 INTRODUCTION
In the evolution of automating the driving task, humans are required to act as a fallback in conditional automation (SAE Level 3) and continue driving in moments the vehicle reaches a limitation [6]. At this specific level, humans may engage and distract themselves with everyday tasks that are not driving-related, such as reading, watching movies and listening to music [5]. On the other hand, it is difficult or even impossible for even highly motivated humans to keep up monitoring automation over long periods if very little happens [1, 4]. However, it is safety-critical that humans react or resume the driving task in a timely manner [6]. It is expected to perform well in this situation that the person with a better awareness about the current situation would perform better compared to a person with less situation awareness [1, 8]. Therefore, they are more likely to prevent a possibly dangerous situation. In our research we aim to design and evaluate interfaces that address the problem of losing the awareness or being out-of-the-loop of the current driving situation in conditional automated driving (SAE Level 3). In this video demonstration, we present a simulator study design of a high fidelity driving simulator study to test our automotive user interface interventions. The study evaluates three interventions:

1.1 T1: Uncertainty Display "Guardian Angel"
The first intervention shows bars on the side that visualise the uncertainty of the automation (e.g. [3]). These indicate how confident the automated driving system currently is. If the bars become smaller and green, the situation is less complex, and the automated driving system is confident with driving. If the bars become bigger and red, the situation is more complex, which means the likelihood is higher that the vehicle reaches a limitation.

1.2 T2: Interruption of Non-Driving Related Activity
The second intervention will hide the display when the situation gets more complex, and asks the fallback-ready user to check the environment to prepare them with the situation. This notification is not a request to continue driving but the likelihood is high that the system reaches a limitation and asks the fallback-ready user to continue driving.

1.3 T3: Combination of T1 & T2, the Uncertainty Display and the Interruption
The third intervention combines both. The bars on the side indicate the uncertainty of the automation. In addition, the system will hide the display when the situation gets more complex, and asks the fallback-ready user to check the environment to prepare them for a potential take over.

2 VIDEO SIMULATION STUDY SETUP
The experiment has a between-group study design with N=215 participants. It took place in the high-fidelity simulator study in the Advanced Driving Simulator1 of the Centre of Accident Research and Road Safety - Queensland (CARRS-Q, QUT). All three treatments (T1, T2, T3=T1&T2 combined) were tested against a baseline without an intervention (2x2) (see Figure 2).

Participants experienced conditional automated driving (CAD) functions with the expectation to continue driving at any time. As previously presented at AutoUI, a video-simulation method was used [2, 7] that has the benefit to "drive" in a real environment familiar to the participants and which has exactly the same driving and weather conditions for each participant. While the CAD system was engaged, participants were allowed to engage in a non-driving related activity (NDRA). The NDRA was the same for all participants and included a series of short, entertaining video documentaries over an Augmented Reality head-up display projected on the road ahead (see Figure 1).

3 EYE-TRACKING OBSERVATIONS
We are using eye-tracking data to find differences in visual attention between the treatments. We report the results of a thematic analysis of observations of a heat-map-split-screen that is overlaid and synchronised with the driving scenario. The heat maps represent the eye-gazes of each group, with over 50 participants equally distributed and counterbalanced in age and gender in each group.

At first, we noticed that participants in both interruption groups (T2 & T3) had interrupted the entertaining task more frequently and regularly to check the road ahead, even though the display was not taken away. This behaviour can be compared to a flame in the wind in the heat map.

Secondly, participants in both interruption groups appear to interact and react better and faster to events in the driving environment, such as other road users or street signs. This effect seems accelerated for the combined treatment group (T3), with interruption and uncertainty display.

Figure 2: Eye-Gaze Heat Map Divided in the Four Treatments

4 VIDEO SUBMISSION
The publication of this analysis is currently in progress. More details of the study, intervention design, results, and discussion will be published soon. We encourage the AutomotiveUI-community to seek discussion with us about your thoughts and the outcome of the results. Find updates on this research at https://github.com/me89/AttentionManagement

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1vehicle on motion platform with 180° field of view video screens in front and all three mirrors replaced by displays
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