HFE in the Connected World
IEA VANCOUVER 2021
L'ergonomie 4.0

The Effect of Different Display Information Load with Take-over Request on Human Takeover in Conditional Automation

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Abstract

This study explores the effect of different take-over request (TOR) interfaces on takeover performance in conditionally automated driving (CAD) and found better takeover performance and driving behavior with the advanced-predictive information load interface. The present study can be used in future designs of automated driving interface.

KEYWORDS: Automated driving, Non-driving related tasks (NDRT), Take-Over Request (TOR), Smartphone

Introduction

With the rising trend of automated driving in the consumer market, CAD is estimated to take over the current domain for partly automated driving. The largest risk to optimizing driver safety and comfort during automated driving occurs when the automation system sends a TOR during the driver's non-driving related tasks (NDRT) while sleepiness and fatigue from reduced driving workload have weakened the driver's response capability to emergencies. Past studies have explored the use of the vehicle's center console as display interface for the main visual output of warnings and prompts (Naujoks et al., 2018; Wandtner et al., 2018). While the driver's reception of and response time to these warning signals may be influenced by factors such as information load and type of warning (Gold et al., 2013), the study by Zeeb et al. (2015) shows that driver's takeover performance may be influenced by different strategies through which the driver monitors the road.

OBJECTIVE:
The objective of this study is to evaluate the degree of display information load required to alert the NDRT-immersed driver of TOR to enable human takeover in the shortest time possible.

Methodology

This study is a 3 x 2 x 2 factor experimental design with 3 degrees of vehicle display information load (basic, predictive and advanced-predictive), 2 types of takeover request (directional and non-directional), and whether there was NDRT immersion or not (see Figure 1.). 48 subjects were recruited and underwent testing with various combinations of said factors to investigate human takeover behavior, performance and subjective feelings.

The STISIM Drive Model 100WS developed by Systems Technology, Inc. (STI) was used as the driving simulator in this experiment, and the virtual road scenarios in the experimental environment were constructed using Scenario Definition Language V8.1.

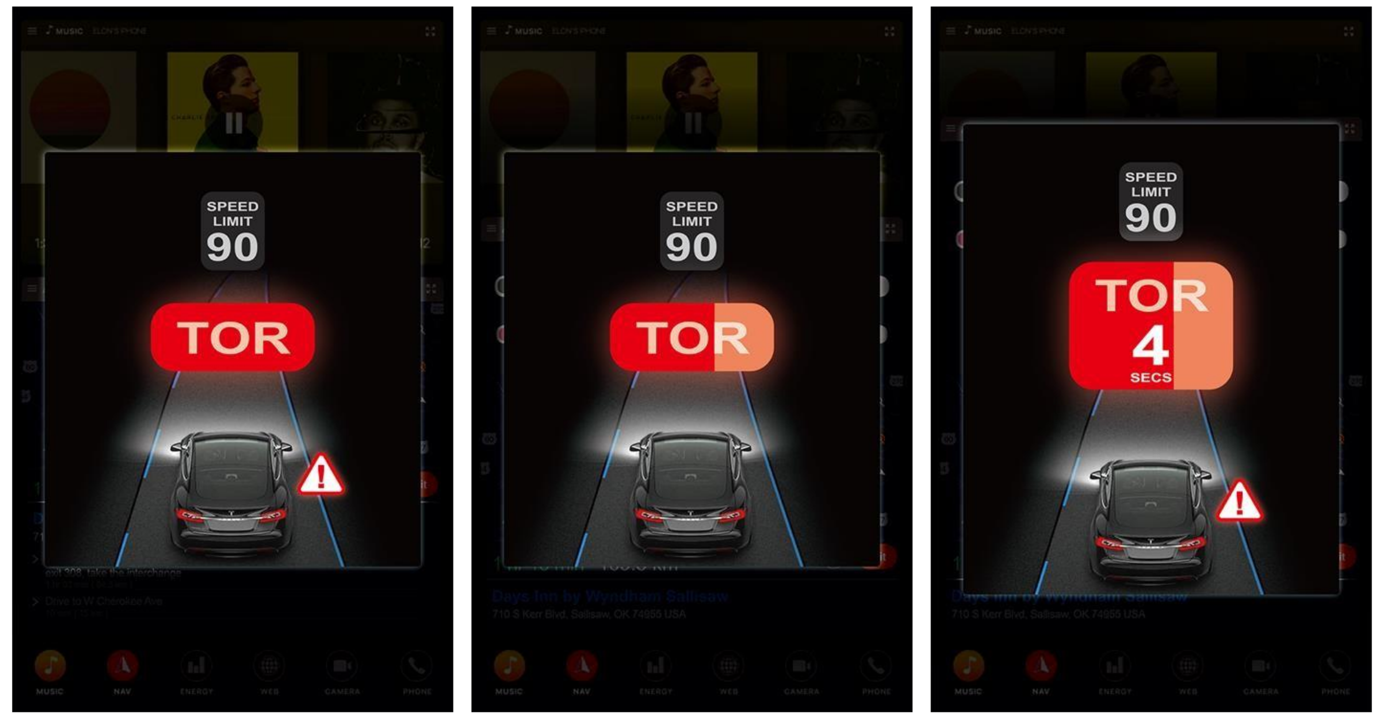

Figure 1. Three types of vehicle display information load: (a). basic interface with directional information; (b). predictive interface without directional information; (c). advanced-predictive interface with directional information

EXPERIMENTAL PROCEDURE
Manual and automated driving were performed eight times each, in an interchanging manner. The automated driving was switched to manual driving every time a TOR prompt was issued by the system. The experimental scenario was designed to ensure that the manual driving was performed for 1–2 min instance and the automated driving was performed for 7–9 min in each instance (8 min on average). To ensure that the participants were familiar with the experimental scenarios and immersed in the experiment, the participant drove manually for the first 1.5 km of the experiment before automated driving occurred. Additionally, the participant was unexpectedly asked to perform the NDRT during this process. During automated driving, the participant would encounter experimentally designed incidents after some time. A TOR prompt was issued 15 s before each incident, and the driver was asked to take control during these incidents to ensure the safety of the vehicle. After taking control of the vehicle, the driver was made to manually drive the vehicle for approximately 1.8 km before switching back to automated driving.

Results

Results showed that human takeover performance was more efficient with the advanced-predictive display information load than basic and predictive, and similar results were found in variations of steering wheel angle, braking and acceleration. All three display information load groups showed shorter takeover time and better takeover performance with directional, rather than non-directional request type. There was no significant difference in the driver's subjective perception between the three information load groups, and the ease-of-use assessment for all three attained excellent system standards, while both the predictive and advanced-predictive information load were rated by the test subjects as interface designs with the best possible outcome.

Discussion

Both takeover time and response time were shorter with directional, compared to non-directional request type – this demonstrates that timely relay of important messages to the driver can effectively improve TOR response and takeover (Alvarez et al., 2011). Furthermore, takeover time without NDRT immersion and response time with NDRT immersion were also shorter with advanced-directive display information load than with basic and predictive display information load, showing the significant effect of the vehicle display interface prompt on takeover (Kiesel et al., 2010). The results also show smaller longitudinal acceleration, steering wheel angle, braking and acceleration in directional request type than non-directional, possibly because no compensation by the driver was needed in the former to control the vehicle. This finding is in line with the study by Zhang et al. (2018) in which directional prompts are considered as one of the important elements of warning messages – messages containing the direction of potential collision risks can provide timely prompts for drivers to prevent collisions.

Conclusion

This study provides an effective display design concept and may be used as a guideline in the future designs for CAD interface.

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