In-Car Distractions and Automated Driving: A Preliminary Simulator Study

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Abstract

As vehicles with automated driving features become more common, drivers may become ever more tempted to engage in secondary in-car tasks. We report on the results of a driving simulator study that investigated whether the presence of an in-car video would make drivers more likely to switch on an automated driving system so that they can watch the video. Results show an increase in automated driving mode usage when a video was playing compared to when it was not playing. The presence of this in-car video also made participants slower at reacting to frequent red traffic lights, which the automated driving mode did not detect and were the responsibility of the driver to respond to. These results suggest that in-car distractions are a critical concern for the safe and responsible use of automated driving systems.

Author Keywords

Partial driving automation; level 2 automation; driver performance; multitasking.

CCS Concepts

• **Human-centered computing** → Human computer interaction (HCI); Empirical studies in HCI.

Introduction

Automated driving systems are becoming increasingly prevalent and sophisticated [7]. These systems have been developed to handle the more mundane aspects of driving, such as maintaining a steady speed and central lane position. Currently available system can perform very well on straight open highways, allowing the driver to focus on other aspects of the driving task.

Previous research has already demonstrated that the use of automated driving systems can lead to drivers abandoning their responsibility for monitoring the road while driving [10]. A critical concern that we focus on here is the potential for in-car multitasking [2,3].

Multitasking is already rife in cars, with drivers often choosing to take their eyes off the road so they can interact with mobile devices [4]. As automated driving systems become more dependable, will drivers become ever more tempted to engage in tasks unrelated to driving? An investigation into the first fatal accident involving the Tesla Autopilot found that the driver was watching a movie just before the crash occurred [1,5].

In this paper, we investigate whether drivers are more likely to switch on an automated driving mode when there is an engaging secondary task for them to do instead of monitoring the road. We report the results of driving simulator study in which participants were free to enable and disable an automated driving mode. We also varied whether or not a video was playing, offering a potential distraction to the driver. We expected participants would be more likely to switch on the automated driving system when there is the option to watch a video, and that this will negatively impact reactions to critical road events that required the driver's intervention.

The reason we had participants respond to critical events is that there are many everyday driving situations that current-generation automated driving systems cannot handle [1]. For example, these systems often cannot detect and respond to traffic instructions, such as stop signs and traffic lights. In these kinds of situations, the driver is responsible for intervening and taking control of the vehicle [6]. There is a growing body of research directed at how best to alert drivers to these critical handover events [8,12,13]. Here, we instead focus on the driver's decision about whether to enable the automated driving mode in the first place.

We also investigate whether the use of an automated driving mode is influenced by the driving environment. What happens if the driving environment requires more frequent handovers of control? Would this make the driver more likely or less likely to disable the automated system and engage with manual driving instead? We investigate this question by varying the frequency of traffic lights that the driver had to monitor and react to. We expected participants to be less inclined to use the automated driving system when there were more frequent traffic lights than when there were fewer.

Method

Participants

Twenty-three (10 female) participants with an average age of 29 years (range: 22-56) took part in the study. Most were students (21 of 23), while one was a professor, and another was a business administrator.

Figure 1: Driving simulator setup with steering wheel, pedals, monitor, and iPad for secondary task.

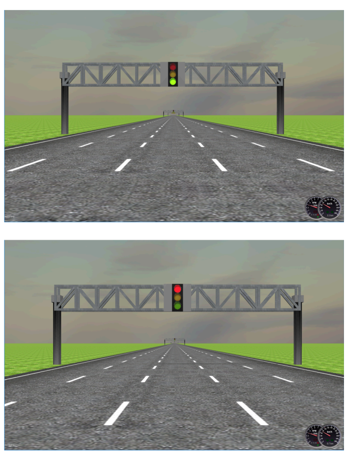

Figure 2: Green (Top) and Red (Bottom) traffic lights as they appeared in the driving simulator.

Design

A 2×2 (Video Presence x Traffic Light Frequency) mixed design was used. Video presence was manipulated as a within-subjects factor and traffic light frequency was manipulated as a between-subjects factor. This meant that each group had different expectations of the frequency of takeover events. The dependent measures were participants' reaction times to traffic lights after they turned red and the proportion of time during a trial that the automated driving system engaged.

Materials

Figure 1 shows the lab setup for the study. Participants were seated in an office chair. In front of the seat was a table with a 31-inch monitor at eye-level. This screen was used to display the simulator. Attached to the table directly in front of the participants was a Logitech G25 gaming steering wheel, with a pedal set positioned under the table. An iPad mini was used to play the video and was placed to the right of the steering wheel.

The driving task was developed in OpenDS (https://opends.dfki.de). Each trial was on a five-lane highway, with awnings placed above the road. Each run had a "Start" and "Finish" awning. All other awnings were randomly placed (with a minimum spacing of 250 meters in between) and included a green traffic light. Some of these would turn red when the driver passed an invisible trigger that was set 50 meters in front of the light (Figure 2).

The simulated vehicle had a Level 2 Partial Driving Automation system. This meant that the vehicle would stay in its current lane and maintain a designated speed when the system was turned on, but it would not react to the traffic lights when they turned red. The system did not notify the driver of any situations where they should take over control. The driver could handover control to the system using the left red button on the steering wheel (Figure 1). The driver could also take over control of the vehicle using the brake pedal or the same steering wheel button. The simulated vehicle had a minimum speed of 10 km/h and a maximum speed of 70 km/h. No other vehicles were on the road. There were no weather effects, and there were no turns in the road.

Two videos were used as a secondary task. The videos were from popular travel blogs found on YouTube. These videos were chosen because they contained content referring to distinct places and events; allowing the participants memory for the content of each video to be assessed after each trial. (We do not report this data because of space constraints.)

Procedure

Participants were randomly assigned to either the frequent or infrequent traffic light group. Participants were given an information sheet and were verbally told they could stop at any point and that they did not need to finish the test. The experimenter next explained the operation of the driving simulator. Participants were told that they were to stay in the middle lane at top speed. Participants were introduced to the traffic lights, and how to respond to them using the brake pedal. Finally, participants were introduced to the functions of the Automated Driving System and how it was limited to maintaining the lane position and speed of the vehicle. Participants were then given a practice run where they enabled and disabled the automated driving mode and used the brake pedal to respond to red traffic lights.

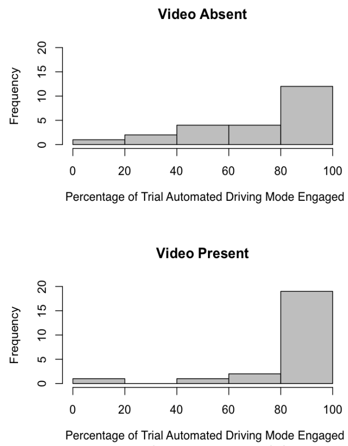

Figure 3: Automated Driving Mode Usage Results Driving simulator setup with steering wheel, pedals, monitor, and iPad for secondary task.

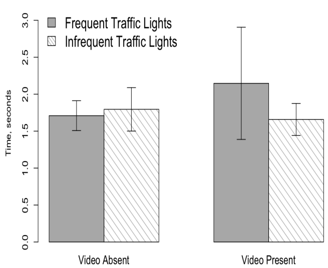

Figure 4: Reaction time to red traffic light events plotted for each run state (Error bars represent standard deviation).

After the training phase, participant completed four experimental runs: two trials with videos playing and two trials without a video playing. For trials in which a video was playing, participants were told that their memory for places and events mentioned in the video would be assessed at the end of the trial. Each trial began with the automated driving system turned on, but control over turning the system on and off was given to the participant immediately. Each trial was started this way to maximize data on automated driving mode usage and takeover scenarios. After these runs were completed, participants were paid £5.

Results

Automated Driving Mode Usage

Figure 3 shows the proportion of time that each participant had the automated driving mode engaged during a trial. It can be seen in the figure that participants were far more likely to enable the automated driving mode when the video was present (bottom panel) than when the video was absent (top panel), $F(1,21) = 9.67$, $p = .005$, $\eta_p^2 = .32$. There was however no effect of traffic light frequency on the use of the automated driving mode.

Brake Reaction Time to Red Traffic Lights

Figure 4 shows the mean brake response time for each condition. There was a significant Video Presence x Traffic Light Frequency interaction effect on brake reaction time, $F(1,21) = 7.76$, $p = .01$, $\eta_p^2 = .27$. Follow-up tests of this interaction found that when the video was present, participants had significantly slower brake reaction times when there were frequent traffic lights ($M = 2.15$s, $SD = 0.76$s) compared to when there were infrequent traffic lights ($M = 1.66$s, $SD = 0.22$s), $F(1,21) = 4.59$, $p < .05$, $\eta_p^2 = .18$. In contrast, when the secondary video was absent, there was no effect of traffic light frequency on brake response times, $F(1,21) = 0.43$, $p = .52$, $\eta_p^2 = .03$.

Discussion

The results of this study show that participants were more likely to enable an automated driving mode when a video was playing that they could watch while driving compared to when there was no video playing. The presence of this video made participants slower at reacting to frequent red traffic lights, which the automated driving mode did not detect and were the responsibility of the driver to respond to. These results suggest that in-car distractions are a critical concern for the safe and responsible use of automated driving systems.

This paper describes the results of a preliminary study that was conducted using a desktop driving simulator. While the effects found in driving simulators do typically reflect those that found on the road [11], there is scope to improve on this. As can be seen in Figure 1, the setup had a low level of fidelity and realism and a future study could be conducted in high-fidelity driving simulator. Related to this the simulated driving environment was rather simplistic: participants were only required to drive along a straight road with no other vehicles. A future study could increase the complexity of the driving environment, for example, by having participants drive along a highway or through a busy city environment, especially as this is known to affect drivers in-car multitasking behaviour [9]. Despite the preliminary nature of these results, this study shows that automated driving systems can encourage in-car multitasking, increasing the risk of driver inattention at safety-critical moments [1,5].

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