Handover assist trials in highly automated vehicles: participant recommendations for future design

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ABSTRACT

Automated vehicles with situation-specific limited driving capabilities will soon be on our roadways. With this, comes the issue of the handover of control. This is required as the automated system reaches a design or capability boundary and requires the human-driver to take control. This is a profound issue, as the driver will have reduced 'situation awareness' due to being 'out-of-the-loop' for an extended period of time. To compensate for this, vehicle designs must make use of handover assist to ensure that situation awareness is effectively transmitted to the driver prior to taking control. In the case of an approaching pre-planned geographical boundary of operation, the handover is non-critical. We draw upon strategies currently practiced in domains such as healthcare, aviation and energy manufacturing / distribution and test four methods of verbal handover in a simulated road environment with a dual-control vehicle. Participants took part in four handover conditions and provided recommendations for the future design of highly automated vehicles. We found six core themes that summarise the recommendations made by the participants of these trials, and draw upon five core implications for future design. Researchers and designers should now look to integrate a number of viable approaches to the handover to create a unified efficient, safe and usable handover protocol for highly automated vehicles. Based on user preferences, we provide some insight on possibilities for application to future design and tests.

KEYWORDS

Handover, high automation, situation awareness

Introduction

In the near future, highly automated vehicles (HAVs) will be on our roadways within specific geographical boundaries (Walker, Stanton, & Salmon, 2015). The vehicle and the human driver will be required to work together as co-pilots. In these vehicles, as automation is reaching a specific design or capability boundary the vehicle will notify the driver to take control. This period of control exchange is known as the 'handover', and represents a major hurdle for automobile companies and engineers to overcome. This is due to a reduction in a driver's 'situation awareness', as a result of being 'out-of-the-loop' for an extended period of time (de Winter, Happee, Martens, & Stanton, 2014; Endsley, 1995), and leads to increased risk following the takeover of control (Brandenburg, & Skottke, 2014; Merat & Jamson, 2009).

In the case of approaching a geographical boundary of operation, the handover is non-critical, as there is no emergency present requiring an action. Drivers are therefore able to take control during what is known as a "comfortable transition time" (Eriksson & Stanton, 2017a; Merat, Jamson, Lai, Daly, & Carsten, 2014). This allows sufficient time to transmit a detailed mental model (Revell &

Stanton, 2012, 2017). Before taking control of the vehicle following an automated period, the driver and the automation must be prepared for the handover. It follows that vehicle designs must factor in the transmission of information both to and from the driver as both agents make decisions (Banks & Stanton, 2016; Eriksson & Stanton, 2017b).

The handover has been conducted in a range of settings for a number of decades and has been typically researched in domains where a failure to transmit information effectively can result in disastrous consequences (Patterson, Roth, Woods, Chow, & Gomes, 2004; Salmon, Walker, & Stanton, 2016). Areas such as healthcare, aviation, and energy manufacturing/distribution all routinely handover because of rotating shifts or the requirement of specialist being present (Adamson, Lardner, & Miller, 1995; Catchpole et al., 2007; Eurocontrol, 2012). As the driver receiving control during a non-critical handover in a vehicle will be in a similar position to that of an incoming operator in another domain, we propose that strategies should serve as a foundation for the design of HAV handover assistants.

For visual handover interfaces, Ecological Interface Design (EID) may prove to be an efficient way of raising situation awareness by capitalising on the sensory-motor capabilities of the driver (Rasmussen, & Vicente, 1989). Other approaches to handover interfaces include that of a vocal assistant (Eriksson & Stanton, 2017b). Vocal handover is a common way of conducting shift handover in a variety of other domains (Patterson et al., 2004). We set out to test a range of verbal handover methods for use in HAVs, inspired by research into shift-handover in other high-risk domains: checklist, read-back, conversation-style, open questioning and a timer.

Method

Strategies were tested in a simulated roadway environment with control input coming from one of two steering wheels on either side of the vehicle, with control exchange being possible at a click of a button. The experiment simulated a control exchange as a result of an approaching junction on a motorway, pre-selected for exit.

Figure 1: Driving simulator set-up to simulate handover between two drivers.

Participants were able to take part in a range of within-subjects handover conditions with the opportunity to provide feedback and recommendations for future design. The handover strategies in the experiment involved the deployment of a structured checklist, much like that in other domains. The structured checklist was constructed inspired by two concepts: IPSGA (Stanton, Walker, Young, Kazi, & Salmon, 2007) and PRAWNS (Walker et al., 2010, Wilkinson & Lardner, 2012). The checklist is as follows:

- 1 – Potential hazards
- 2 – Current position on roadway
- 3 – Fuel status
- 4 – Speed
- 5 – Future pre-planned goals
- 6 – Future action required

Four handover methods were tested, inspired by shift-handover literature.

- Checklist with read-back confirmation (see Boyd et al., 2014)
- Checklist with interactive conversation-style questioning
- Open questioning (see Rayo et al., 2014)
- A timed handover with no information transfer (60 seconds countdown)

All participants took part in all conditions; counterbalanced using a balanced-Latin square. After participating, participants were asked, "Imagine you had been on a motorway journey in a highly automated vehicle in automated mode and had been conducting a distractor task for two hours prior to handover (e.g. sleeping). How would you like information to be displayed to you for the purposes of the handover of control?" A space was provided for participants to share thoughts through either writing or drawing their ideas.

Results

Forty participants provided their recommendations for future design for handover assist in highly automated vehicles. Participants' responses were coded and grouped into six core themes. Themes and the frequency of their codes are displayed in Figure 2.

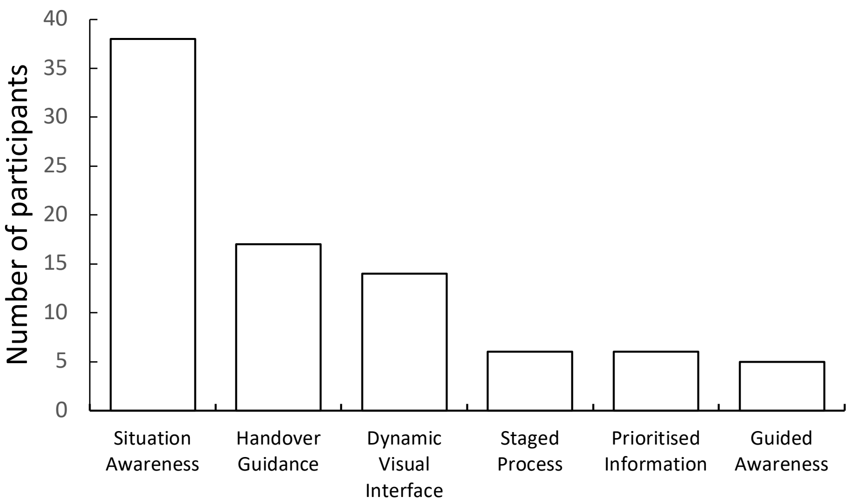

Figure 2. Themes generated from responses and frequency of participants commenting on them

Situation Awareness

All but two of the participants made recommendations on how automation can handover important information. Information types recommended and their frequencies are outlined in Figure 3.

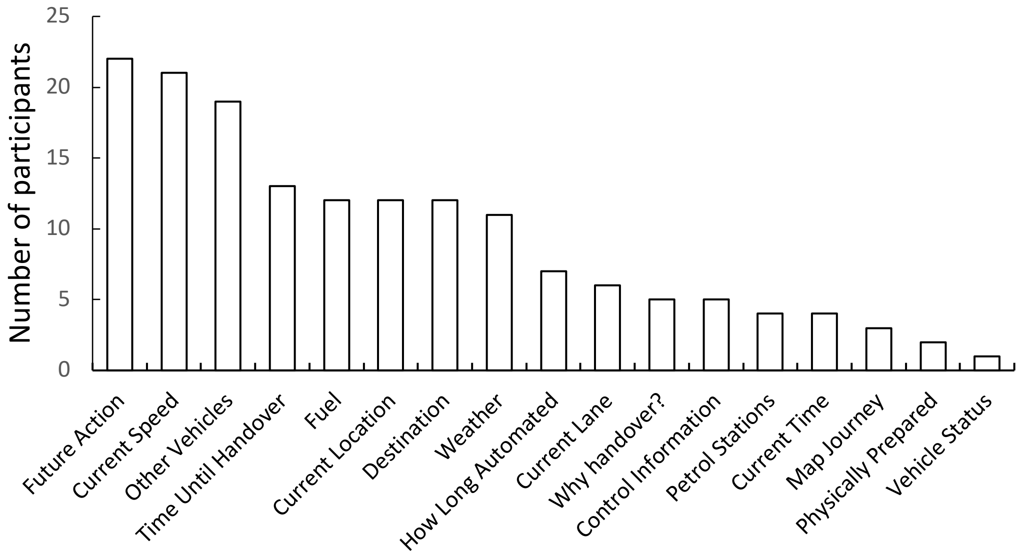

Figure 3: Information types generated from responses and frequency of participants commenting on them

It was commonly stated that various types of information should be vocally transmitted whereas other types of information were more suited to visual displays. Commonly, information such as fuel and speed that is currently displayed on interfaces in currently available automobiles should remain there e.g. *"Speed and fuel would be best displayed"* (Participant 23);*"verbally: traffic/weather conditions, visually: fuel, miles travelled and route info"* (participant 29). Whereas other information types were typically desired within both vocal and visual streams e.g. *"Verbal and displayed: Distance to destination, traffic conditions and weather conditions"* (Participant 26). Some people preferred information presented on displays with directional information given vocally, e.g. *"I'd want to see a pictorial image of cars around me. Vocally, I'd want to know how close I am to my junction or destination, and I'd want to know why I have to take control."* (Participant 22).

Participants frequently stated that they did not want information vocally given if they can quickly gauge it for themselves, e.g. *"Typical information such as speed and traffic immediately around me would be something I can see without the AI, so I do not prefer to hear that"* (participant 36); *"verbally – everything except what's in front of the car"* (participant 27). They were also likely to request why the automation was handing over, and what the car wanted the driver to do in the future.

Handover guidance

One of the most common recommendations was the desire for aids related to the logistical side of handing over control. These comments represented a system where there are clear warnings, timers, and verifications of control transfer. Examples of notifications included calling out the name of the driver (participant 35), and a vibrating seat (participant 6). Countdown timers were commonly requested, although a mix of both vocal and visual countdowns were mentioned, e.g. *"Countdown gives plenty of time to get settled"* (participant 9); *"Interfaces with speed, map and fuel, switches to a timer, then an indicator to drive"* (participant 11).

Finally, participants commonly cited the need for control confirmation, such as a three-step traffic light system (participant 3) or reassurance from the system that control has been transferred (participant 19).

Dynamic visual interface

Complimentary to the handover, a dynamic interface with information deemed important for the handover was commonly recommended. Participants took the opportunity to draw interfaces that they think would be suitable for these vehicles. Participants either displayed information as a single screen (participant 1), a timed screen dependent on stage of handover (participant 11), or a manually scrolling screen (participant 7). All of which provide the information cited in the "situation awareness" theme above. Interfaces provided information in congruence with verbal cues (e.g. participant 28), as well as presenting unique information such as fuel and speed (participant 35). Information such as surrounding vehicles (participant 12), maps (participant 11), and route information (participant 29) were also commonly requested.

Staged process

Another important aspect that participants drew upon was the requirement for the handover to be separated into before, during and after, with different types of information and guidance being presented at each stage. The 'before' stage typically involved general awareness and receiving a mental-model of the situation. The 'during' stage involved coordination such as timings and status of control (e.g. participant 9). After handover, information such as the confirmation of control and route information was desired (e.g. participant 27). Further, participants also highlighted that information may need to be updated after the handover had been completed (e.g. participant 19).

Prioritised information

Some participants felt that some information should only be presented if the knowledge needed to be known. One participant stated, *"more than five miles away and I don't need to know yet"* (participant 28). Information such as low fuel, critical effects on the car and dangerous weather should be prioritised. Participants also highlighted that some information types should take precedence during the handover update. This included important information such as traffic and blind spots (participant 27), as well as stating that all safety related information should always be told (participant 36).

Guided awareness

Aside from explicit information transfer, some participants felt that attention should be drawn to important aspects of the driving scene in real-time, through technology such as head-up-displays, or an option to ask for more information from the system (e.g. *"maybe an option to ask for more information",* participant 9).

Discussion

Our results show that common recommendations for handover assist include the transfer of useful information, provision of clear coordination and successful transmission of expectations to driver. How this is operationalised appears to be subject to individual preference.

Generally, information that was more difficult to gauge visually was preferred as verbal feedback. This includes information such as location, future actions, and coordination information such as time to handover. However, many participants stated that they wanted other types of information to be fed back verbally, whereas others preferred a handover assist centred on an interface. Regardless of method, participants seem to be open to the idea of a handover assistant that transfers a wealth of information regarding the driving task.

From a design perspective, five main requirements can be derived from these results:

- A clear transfer of a complete mental-model of the situation
- The requirement for continuous assist following the handover
- Multiple streams of information (visual, oral and haptic)
- A transparent, coordinated protocol for handover
- A degree of personalisation to fit individual preferences and situation context

Many of these recommendations reflect those from the shift-handover literature (e.g. Cohen, Hilligoss, & Amaral, 2012; Durso, Crutchfield, & Harvey, 2007; Patterson et al., 2004), although research is limited on how this can be applied to HAV handover. Research is also limited on how these elements can be drawn together to create an approach to handover that is time efficient, safe and usable from a driver's perspective. Possible applications are discussed below.

Many participants made it clear that safety information was important and should always be presented. As an example, dynamic interface information about nearby vehicles and how the current vehicle relates to them in the environment could be implemented through innovative head-up displays, as well as a verbal assist to guide attention. This would allow drivers to build their own mental model through perceiving threats in real-time. Verbal assist could communicate priority and contextual information (e.g. low fuel) and advise on future action required. Concurrently, interfaces could be a platform for the user to interact with automation prior to handover.

This research lays the foundations for further work that could look at how providing more or less types of information may affect driver behaviour and physiology. It is one thing to know what drivers want but another to know what drivers need. Indeed, there may be limitations in applying everything that drivers desire, as this may lead to slower task processing (Omodei et al., 2005). Therefore, it may be suitable to test combinations of information types to ensure information availability is well calibrated. Another consideration is that drivers may be more visually vigilant, aroused, or control the car differently based upon what information is provided prior to handover. Drivers also note that dynamic interfaces would be beneficial to them during handover. It may be that a synergy of EID and vocal interfaces can be used to potentially reduce workload and provide a safer and smoother handover. These results are high-level and should be an indication of information-types to be explored. Detailed guidance on what should be presented in each category can also be a focus of future research. It is hoped that these preferences will provide a basis on which future designs can be designed and tested.

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