Taking control without guidance: What do drivers of semi-autonomous vehicles think about?

Kirsten Revell, David Keszthelyi, James Brown & Neville Stanton

University of Southampton

ABSTRACT

Cars that can drive themselves are nearly with us and semi-autonomous vehicles are already on the road. The largest gap in our understanding of vehicle automation is how drivers will react to this new technology and how best to design the driver-automation interaction. This study focuses on what drivers pay attention to at different stages of a planned handover from vehicle to driver. Thematic analysis was conducted on think aloud 'verbal protocol data' from drivers interacting with a SAE (Society of Automotive Engineers) L3 semi-autonomous vehicle using a driver simulator. Focusing particularly on verbalisations indicating Situation Awareness (SA) which is linked to safe transfer of control, and post handover drive, the type and proportion of verbalisations before, during and post handover was captured. During handover, it appeared that drivers minds were directed towards the interaction rather than the road ahead, suggesting safety may be compromised. Examining pre-handover data it was seen that SA verbalisations were very prominent in the 20 seconds prior to engagement when it was expected that drivers would be focused on their secondary task. A level of vigilance pre-handover may therefore negate the frequency of SA verbalisations during handover. The nature of SA verbalisations also change at different stages of handover. Pre and during handover there is a far greater emphasis on 'checking road conditions' and commenting on 'positive road conditions' compared to post handover where the focus is on other road vehicles and speed. Implications for interaction design in semi-autonomous vehicles is discussed.

KEYWORDS

Handover; Semi-autonomous vehicles; Situation Awareness; Safety; Thematic Analysis;

Introduction

Self-driving cars have been predicted for some time, and are nearly with us. Semi-automated cars (SAE (Society of Automotive Engineers) Level 2) are already on public roads and within 10 years, highly automated (SAE Level 3+) cars will be a reality. The largest gap in our understanding of vehicle automation is how drivers will react to this new technology and how best to design the driver-automation interaction. SAE Level 3 automation offers unique challenges to interaction design. At this level of automation, drivers may engage with a secondary task (e.g. emails, mobile phones) during automated periods of a journey. However, should the boundaries of automation capability be breached, either because of road conditions, weather or lighting conditions, the driver has to be in a state of 'readiness' to safely take control of the vehicle. Reasons why a boundary may be breached may be planned or unplanned, as well as emergency or non-emergency. In this paper

we are focusing on planned, non-emergency handover from vehicle to driver, whereby a driver needs to take control of a vehicle.

Handover in semi-autonomous cars provides conditions where safety can be compromised (Banks et al 2018). According to Stanton et al. (2017), if there are inadequacies in Situation Awareness (SA) it can lead to a disproportionate number of incidents post handover (Thomas et al. 2013). In 2015 Volvo provided a concept car of a SAE L3+ vehicle (Volvo Cars: Explore the User-Interface of Tomorrow). This concept catered for autonomous capability in certain road conditions with a known handover point due to a change in road conditions. The interface provided a graphical countdown timer without evidence of an alert, and required a deliberate action by the driver to regain manual control of the vehicle. No guidance for SA or preparation for manual driving was evident. To better understand how drivers of semi-autonomous vehicles would interact with this type of interface, in particular, how it would support ensuring adequate SA for a safe handover, a simulator study was conducted. This paper considers a single data output from this study in the form of verbal protocol analysis. By understanding what people pay attention to throughout the handover process, when interacting with a concept design that does not provide SA guidance, the appropriate support could be developed to ensure safe handovers in semi-autonomous vehicles.

Method

Participants

Data were collected from 60 participants (30 male, 30 female) equally distributed between 3 age groups (18-34; 35-56, 57-82). All participants were holders of current UK driving licenses and did not have prior experience of SAE Level 3+ automated vehicles, although most had experienced some form of SAE L2 features in vehicles (e.g. cruise control). Ethical approved was granted (ERGO No. 29615).

Equipment

The driving simulator consisted of a Land Rover Discovery Sport, in combination with three frontal screens, providing a 140deg field of view. Door mirrors employed LCD screens and the rear view mirror reflected a rear mounted projection. STISim Drive® Version 3 simulator software provided the virtual environment and a custom route was created comprising two lengths of highway, separated by sliproads to roundabouts, followed by two urban stretches, separated by roundabouts to provide a context of a road condition that could require a planned transfer of control from vehicle to driver. Road conditions were consistently dry and well lit with a traffic density of approximately 1 vehicle per 500ft in all lanes. It was possible to simulate either automated or manual driving by pressing buttons on the steering wheel (labelled ‘A’ for automated, ‘M’ for manual) The vehicle’s cluster was replaced by a Microsoft Surface tablet running a custom dashboard. This displayed a simulated version of Volvo’s concept for a ‘Timer’ based interaction, showing a visual countdown when there were 60 seconds left until a planned Vehicle initiated handover from Vehicle to Driver (Volvo Cars, 2015). To collect driver behaviour and verbalisations four webcams, covering multiple angles within the vehicle were installed.

Procedure

Participants were briefed on the concept of SAE L3 Automation and told that the experiment was investigating handover of control in semi-autonomous vehicles. Specific reference to SA was not made, to avoid biasing the participant’s verbalisations. Participants were trained in the ‘think aloud’ process to generate verbal protocols for analysis using footage from two different video examples. They were then given a period to practice verbalisation whilst familiarising themselves with the

simulator and handover process. This process typically took 15 minutes for participants to feel comfortable and prepared with the system and verbalisation technique. Verbalisations were chosen as Salmon et al., (2017) demonstrated that driver behaviour was comparable with and without concurrent verbal protocols. Participants were advised prior to the drive where all transitions of control were to take place using a map of the route. They instructed to take control of the vehicle before the timer reached zero, as long as it was safe to do so. The route took approximately 20 to 25 minutes to complete.

Analysis

Verbal protocols for each participant were coded according to seven thematic areas devised following a pilot study (table 1). Themes were developed to understand the full scope of driver 'think aloud' content, but as SA content was of key interest, it was further broken down into seven areas. Five of these areas were pre-determined based on 'best practice' of specific areas that a driver should pay attention to during driving manoeuvres following advice from Roadcraft (Roadcraft 2013). The remaining two area (shown in italics) represented more 'general' statements that could not be easily categorised by the pre-determined categories (see table 1). The time periods for analysis are shown in table 2. The primary focus of analysis was to understand 'during' and 'post' handover periods. The 'pre' handover period was subsequently coded to provide a more complete context within which to interoperate these findings. Video data was used to identify the 'Point at which Timer is acknowledged' and 'When 'M' button is pressed'. Verbalisations were then categorised according to the themes in table 1. Counts of verbalisation themes are presented in figure 1 and 5. However, as the time period varied between stage of handover, pie charts were used to better represent the proportion of focus on SA at a broad and more detailed level (see figures 2,3 & 4). Preliminary results only are provided, with full analysis contributing to a future journal paper.

Table 1 Thematic categories for Verbal Protocol Analysis (VPA)

High Level Thematic Areas	Breakdown of SA Thematic area
Situation Awareness	Specific awareness of other road users / hazards/ traffic events in the environment
System Interaction	Awareness of Speed / Acceleration
Secondary Task	Awareness of lane position / need for lane change
Performance Evaluation	Awareness of Navigation (e.g. exit to take or destination)
Readiness for Handover	Action Post Handover (e.g. changing lanes or taking exit)
Experiment Queries	*General 'positive about road conditions' (but not naming specific elements) (e.g. 'road looks clear'*
Being Unsure	*General 'checking road conditions' (but not naming specific hazard)*

Table 2 Time periods for different stages of handover.

Times	Pre-Handover	During Handover	Post-Handover
Start	20 Seconds before Timer is acknowledged	Point at which Timer is acknowledged	When 'M' button is pressed
End	Point at which Timer is acknowledged	When 'M' button is pressed (mean time=38.6s)	10 Seconds after 'M' button is pressed

Results

The count overall count of verbalisations per theme are shown in figure 1. Within the SA theme, the count of verbalisations is broken down before, during and post handover in figure 5.

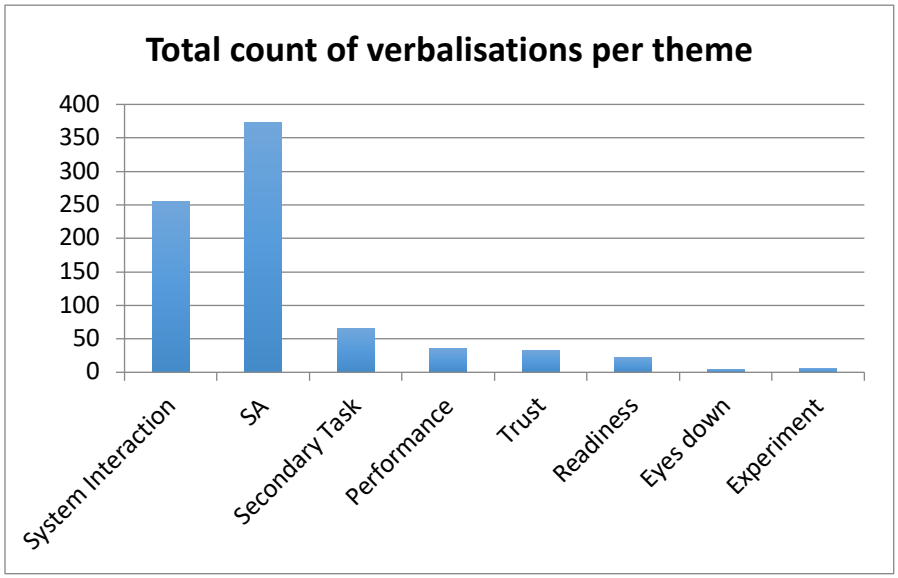

Figure 1 - Total count of verbalisations per theme

Figures 2 and 3 indicate a shift in what drivers think about during and post handover of control.

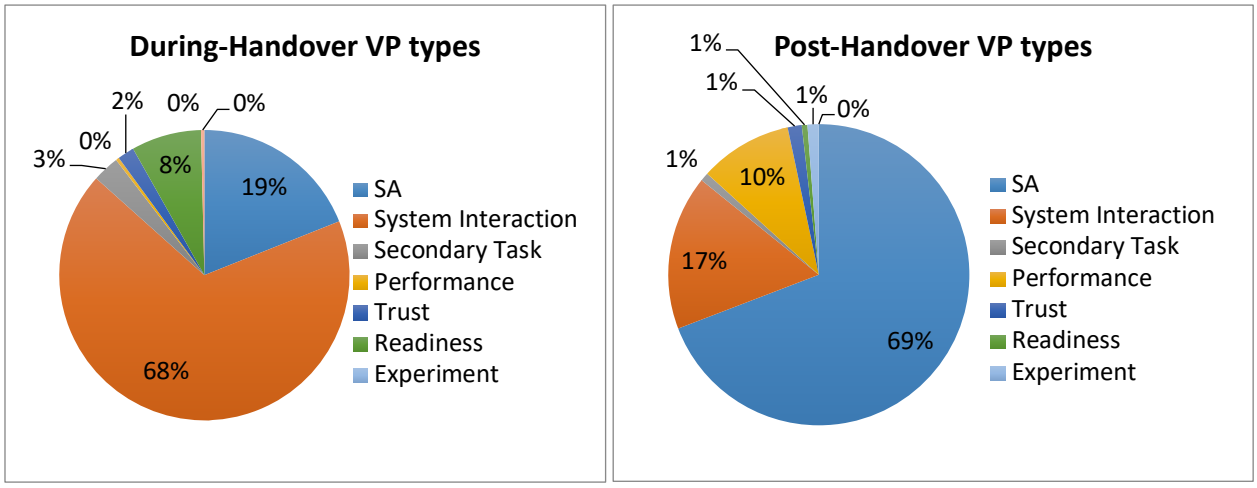

Figure 2 – Pie charts to compare During Handover (left) and Post Handover (right) verbalisation themes

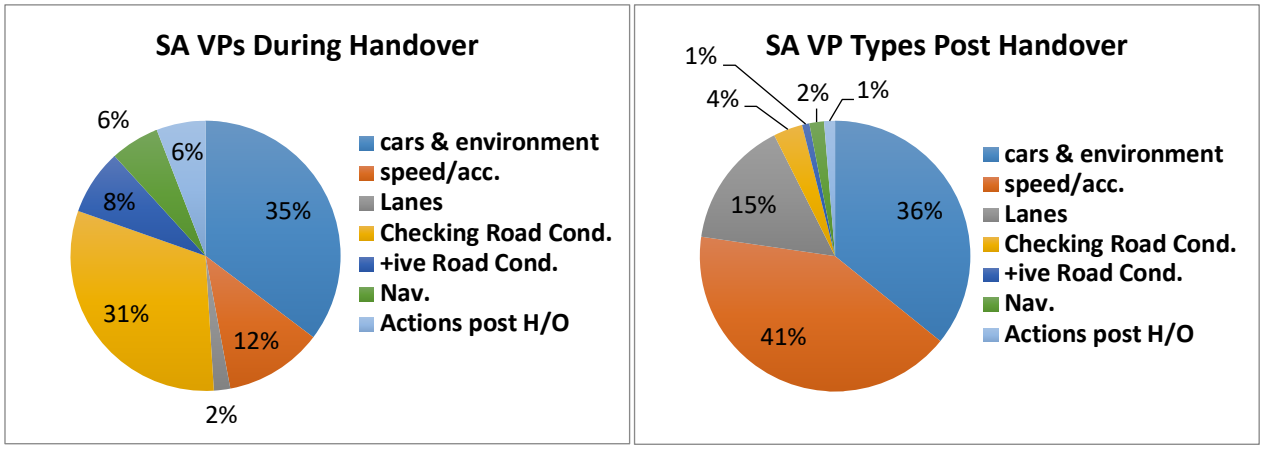

Figure 3 - Pie charts to compare During Handover (left) and Post Handover (right) SA verbalisation themes

Figure 4 shows pre-handover a drivers' attention is not primarily focused on the secondary task.

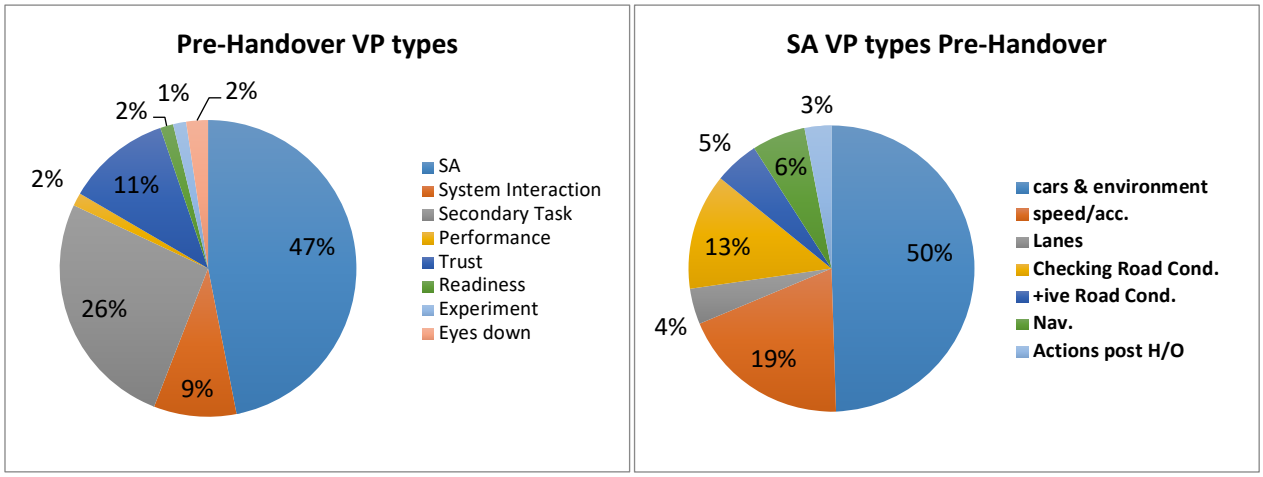

Figure 4 - Pie charts to compare Pre-Handover verbalisation themes (left) and Pre-Handover SA verbalisation themes (right)

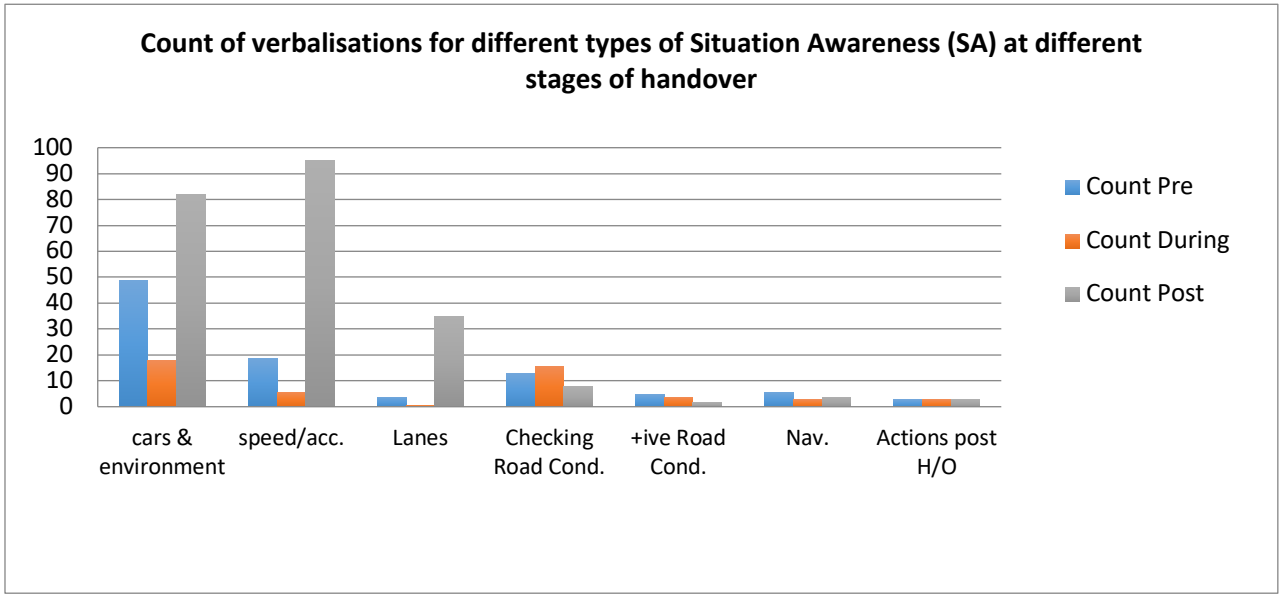

Figure 5 - Count of SA verbalisations by stage of handover

Discussion

This study was conducted to understand what drivers think about during the process of a planned, non-emergency handover of control from vehicle to driver. By understanding what people pay attention to throughout the handover process, when interacting with a concept design that does not provide an alert nor SA guidance, the appropriate support (e.g. through design or training) could be developed to ensure safe handovers in semi-autonomous vehicles.

Thematic analysis of 'think aloud' data during and post handover indicated that drivers paid more attention to interaction with the system (68%) than situation awareness (19%) during handover and the trend is reversed post-handover (figure 2). This has implications for safety as it suggests that during the critical transition period where there are dynamic changes in road conditions, drivers are not prioritising assessment on the outside world. From this analysis, it would be easy to justify that a major focus on SA guidance is warranted.

However, this simple analysis may be misplaced. When considering the SA content in more details in figure 3, it is clear the type of SA information differs in these stages. During Handover a large proportion of verbalisations are geared towards checking road conditions (31%) and describing positive road conditions (8%). Post Handover, these themes reduce to 4% and 1% respectively. This increase during handover reflects a desire to ensure the conditions are appropriate for the handover suggesting safety conscious intentions. In addition, statements such as 'the road ahead looks clear' may cover a number of different observations of vehicles and road context expressed in a single statement, so reducing the incidence count.

Data analysis of the pre-handover stage also suggest a reason for lower than expected incidence of SA verbalisations in the during-handover stage. Figure 4 shows that in the 20 seconds prior to noticing the countdown to handover had commenced, only 26% of verbalisations were focussed on the secondary task, compared to 47% falling into SA themes. Pre-handover, 13% and 5% respectively of SA verbalisations are focussed on checking road conditions and commenting on positive road conditions.

Drivers were aware through their familiarisation session that the handover interface inspired by the Volvo future concept did not provide an alert at the start of the countdown nor any guidance about preparing for a safe handover. This may have inspired more 'vigilant' behaviour in the driver, so they naturally felt a need to monitor the safety of the environment during the autonomous drive, or at least as the conditions as the planned handover of control approached. This is reflected in the far higher proportion of verbalisations relating to 'trust' in this stage of handover (8%). If road monitoring had already occurred before the countdown stage it may indicate key SA has already been achieved in the pre-handover stage. This would sanction the focus by the driver on system interaction in the during handover stage, with SA focus geared much more towards checking the road conditions remained sufficient for handover, rather than assessment from scratch.

Overall, the data appears to indicate shifts in attention that reflect the shift in task parameters. Pre-handover attention is focused on maintaining SA, conducting the secondary task, trust and system interaction. During handover, drivers focus on system interaction, SA and readiness. Finally, Post-handover, their attention is spread across SA, system interaction and performance.

Practical implications

Interventions to assist SA for safe planned, non-emergency handover in a SAE level 3+ could occur in an intelligent vehicle in a number of way: i) using a Head Up Display to highlight the road situation could help prepare the driver pre-and during handover; ii) Using verbal or textual checklists (sanctioned by best practice from motoring bodies such as Roadcraft) to ensure the driver has sufficiently established conditions are safe to take control of the vehicle would be relevant during handover (rather than pre-handover, as this could interfere with the secondary task); iii) finally, providing driving test specific training for interacting with semi-autonomous vehicles (i.e. detailed guidance and practice similar to learning to parallel park or enter a roundabout) would be beneficial for drivers to understand different responsibilities at different levels of automation.

The original analysis of this study looked to focus on during and post handover only, indicating the need for SA guidance during handover. These initial findings suggest that consideration of the pre-handover stage is warranted in the design of any intervention to improve safety. If drivers are already sharing their attention between their secondary task and assessment of the road ahead, pre-handover, then the style of guidance 'during' handover may need to be tailored to *changes* in road conditions rather than highlighting all aspects relating to safe SA for the handover task. Recognition that attention will be diverted on the method of 'intentional' handover is helpful when assessing what drivers think about.

This is preliminary work which raises a number of interesting questions. Should SA guidance be designed to support safe handover only 'during' handover to increase trust in automation and encourage drivers to pay attention to their secondary task. Alternatively, is omitting an alert for planned in SAE level 3 vehicles a positive design feature to increase vigilance during pre-handover phases? If so, how would this affect customer take-up given the marketing of SAE L3+ semi-autonomous vehicles is to free up the 'mind' to focus on other things. Alternatively it may indicate that for planned handover an extended period is needed in the 'during handover' phase, whereby 'core' SA guidance precedes a focus on system interaction with only 'changes to SA' during this period. Further work already undertaken will compare these results to an interaction design with alert and SA guidance in order to determine the pros and cons of different approaches to a safe handover. Resulting designs following these insights will be tested both in test track and on-road studies to ensure generalizability of results and a longitudinal study is planned to understand how drivers needs change with experience.

Acknowledgments.

This work was supported by Jaguar Land Rover and the UK-EPSRC grant EP/011899/1 as part of the jointly funded Towards Autonomy: Smart and Connected Control (TASCC) Programme.

References

Banks, Victoria and Stanton, Neville (2016) Keep the driver in control: automating automobiles of the future. [in special issue: Transport in the 21st Century: The Application of Human Factors to Future User Needs] *Applied Ergonomics*, 53, part B, 389-395.(doi:10.1016/j.apergo.2015.06.020).

Roadcraft, 2013 The Police Driver's Handbook. London. The Stationary Office.

Salmon, P.M., Goode, N., Spiertz, A., Thomas, M., Grant, E. and Clacy, A., 2017. Is it really good to talk? Testing the impact of providing concurrent verbal protocols on driving performance. Ergonomics, 60(6), pp.770-779.

Stanton, N. A., Salmon, P. M., Walker, G. H., Hancock, P. A., & Salas, E. (2017). State-of-science: situation awareness in individuals, teams and systems. Ergonomics, Manuscript, 60(4), 449-466. doi:10.1080/00140139.2017.1278796

Thomas, M.J., Schultz, T.J., Hannaford, N., & Runciman, W.B. (2013). Failures in transition: Learning from incidents relating to clinical handover in acute care. Journal for Healthcare Quality, 35(3), 49-56. doi:10.1111/j.1945-1474.2011.00189.x

Volvo. 2015. Introducing Volvo Interface for Self-Driving Cars. Accessed: https://www.youtube.com/watch?v=19Zf6BWbBFA