Visual attention and steering wheel control: From engagement to disengagement of Tesla Autopilot

Alberto Morando, Pnina Gershon, Bruce Mehler, and Bryan Reimer
MIT Agelab, Massachusetts Institute of Technology, Cambridge, MA, USA

Previous research indicates that drivers may forgo their supervisory role with partial-automation. We investigated if this behavior change is the result of the time automation was active. Naturalistic data was collected from 16 Tesla owners driving under free-flow highway conditions. We coded glance location and steering-wheel control level around Tesla Autopilot (AP) engagements, driver-initiated AP disengagements, and AP steady-state use in-between engagement and disengagement. Results indicated that immediately after AP engagement, glances downwards and to the center-stack increased above 18% and there was a 32% increase in the proportion of hands-free driving. The decrease in driver engagement in driving was not gradual over-time but occurred immediately after engaging AP. These behaviors were maintained throughout the drive with AP until drivers approached AP disengagement. In conclusion, drivers may not be using AP as recommended (intentionally or not), reinforcing the call for improved ways to ensure drivers' supervisory role when using partial-automation.

INTRODUCTION

Tesla Autopilot (AP) is a bundle of features that assist drivers in the longitudinal (traffic-aware cruise control, T-ACC) and lateral (Autosteer) control of the vehicle. AP is considered one of the most capable commercially available systems (Consumer Reports, 2020) but it still requires constant driver supervision (Tesla, 2019). As such, AP can be classified as a SAE Level 2 automated driving feature (SAE, 2018).

Systems like AP are primarily marketed as comfort features that reduce driving demands, although they may also provide added benefit through increasing safety margins (General Motors Corporation Research and Development Center, 2005; Malta et al., 2012). However, the potential safety benefits of automation are still debated (Mueller et al., 2021; Seppelt & Victor, 2016). For example, the use of AP in the period before its disengagement was associated with an increase in visual inattention (longer and more frequent off-road glances), and a reduction of direct control (more frequent hands-free driving), indicating that driver behavior when using AP may undermine potential safety benefits (Morando et al., 2020).

These behavioral changes may be a consequence of a misunderstanding of the proper use of AP and false expectations that are reinforced when automation performs relatively well (Abraham et al., 2017a; Abraham et al., 2017b; Lin et al., 2018; Seppelt et al., 2017; Seppelt et al., 2019; Seppelt & Victor, 2016; Teoh, 2020). Given these behavioral changes, drivers may be unprepared to regain manual control when automation reaches its operational limits (Lin et al., 2018; Parasuraman & Riley, 1997; Reagan et al., 2020; Victor et al., 2018). High-profile crashes, reportedly caused by misuse of AP (National Transportation Safety Board, 2020a, 2020b), have resulted in calls for further research on driver behavior with automation (National Transportation Safety Board, 2020c) and for a more comprehensive way to manage drivers' engagement (Llaneras et al., 2017; Mueller et al., 2021; Reimer, 2020).

This study examines the time course of drivers' visual attention and steering wheel control from just before the engagement of AP, through a steady state of AP engaged, to its disengagement back to manual driving. The aim was to understand if the increase in inattention and the release of direct control was dependent on the time course across these periods. This study provides objective data on how drivers routinely use automation and the associated behavioral changes in driver attention and direct vehicle control. The findings build upon earlier work around the disengagement of AP (Morando et al., 2020) and may further inform the design and development of automated driving systems that can enhance both comfort and safety.

METHODS

Data source

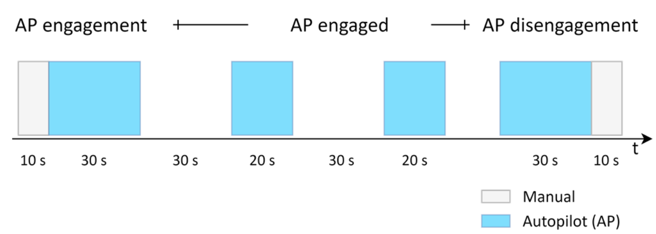

Figure 1. Autopilot (AP) engagement epochs consisted of 40 s of driving data 10 s before and 30 s after the engagement of AP. AP disengagement epochs consisted of 30 s before and 10 s after disengagement of AP. Finally, AP engaged epochs consisted of multiple, non-overlapping 20 s periods of driving data with AP engaged every 30 s between AP engagement and disengagement.

Data are drawn from the ongoing MIT Advanced Vehicle Technology (MIT-AVT) naturalistic driving study (Fridman et al., 2019). The project started in 2016 and has followed owners of Tesla Models S/X driving their vehicles in real traffic for several years. The RIDER (Real-time Intelligent Driving Environment Recording) data acquisition system (Fridman et al., 2019) continuously collected data from: (i) the controller area network (CAN) bus to determine vehicle kinematics, driver interaction with the vehicle controllers, and the state of in-vehicle automation systems (e.g., AP state), (ii) a Global Positioning System (GPS) to record mileage and location; (iii) three 720p video cameras that continuously recorded (30 fps) the driver's posture, face, and the forward view of the vehicle.

The camera recordings were used to extract features related to driver behavior and driving environment.

This analysis is based on a representative subset of 1087 trips (about 21k miles; for details on the selection criteria see Morando et al., 2020). Vehicles were equipped with either AP version 1 or 2, where AP version 2 provides upgraded computing power and sensors. From these trips, we extracted a collection of driving segments (video & CAN data) around transition from manual driving to AP (henceforth *AP engagements*), the transition back to manual driving (henceforth *AP disengagements*), and during steady state driving with AP on (henceforth *AP engaged;* Figure 1). AP state change was identified on the basis of CAN values and then verified in video. The segments were selected according to the following inclusion criteria:

- Driving manually for at least 10 s before activating AP;
- AP used for at least 60 s before disengagement;
- At least 10 s of manual driving after AP disengagement;
- AP used in free-flow highway driving conditions (speed above 30 mph);
- No safety relevant events - excluding segments with frontal collision warning, autonomous emergency braking events, AP take-over requests, or when the longitudinal deceleration was above 3 m/s^2.

Data reduction & annotation

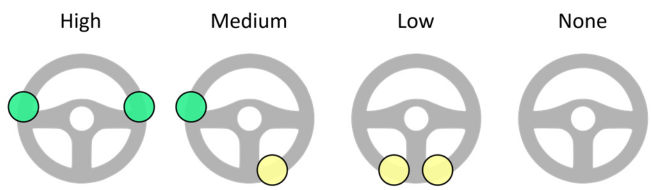

Figure 2. Examples of steering wheel control level. Circles represents hands on the steering wheel. If a hand is positioned on an optimal control position (i.e., 3-9 o' clock) it is highlighted in green. Otherwise, it is highlighted in yellow.

Each driving segment video was manually annotated for glance location and steering wheel control level frame-by-frame at 30 fps by experienced coders. Glance location was classified into six categories: (i) *Road* (any glance directed outside the windscreen); (ii) *Instrument cluster* (any glance to the instrument cluster or the steering wheel region); (iii) *Down & Center-stack* (any glance to the center stack, the in-car multimedia touch-screen, or down as when looking at a smartphone or other object in the lap region); (iv) *Side windows & mirrors* (any glance to the left or right windows or mirrors); and (v) *Rearview mirror*. When a glance did not fall under the categories above, it was coded as (vi) *Other*. The *Other* category contains non-specific glances away from the road. For example, over the shoulder glances, glances towards objects positioned at head level or higher, but also those rare moments when the eyes were closed for longer than a typical blink duration (0.3 s). If the driver's eyes were temporarily not visible due to lighting conditions, etc., glances were coded as (vii) *Not available*. Lastly, following ISO 15007-1:2014, a single glance consisted of the transition time toward an area of interest and the subsequent dwell time on that area.

The level of a driver's steering control was based on the observed hand positioning on the steering wheel (De Waard et al., 2010). We identified four levels of steering control (Figure 2): (i) *High* steering control (both hands on the steering wheel at the optimal 3-9 o'clock position—the pose generally learned in driving school); (ii) *Medium* steering control (only one hand at the 3-9 o'clock position, and the other one was elsewhere on the steering wheel); (iii) *Low* steering control (both hands were not at the 3-9 o'clock position, or when only one hand was placed on the steering wheel regardless of its position); (iv) *None* (no hand grabbing the steering wheel—hands-free driving); (v) the *Other* category was used in cases where the steering control level did not fit the categories listed above (e.g., hands hovering, steering with a knee); lastly (vi) the *Not available* label was used when the driver's hands were momentarily not visible.

The data selection and reduction procedure resulted in 142 *AP engagements*, 161 *AP disengagements*, and 1260 *AP engaged* epochs that could be fully annotated for both glance location and steering wheel control level (i.e., less than 50% of the frames of each driving segment were labelled as *Not available*). The epochs were from 140 unique trips by 16 drivers (3 females), with an age range of 24 – 79 (mean=49, SD=15) and who used their vehicle for an average of 1 year (SD=0.5). Most of trips (n=123) were with AP version 1 and were recorded between May 2016 and December 2018.

At any given timestamp, we computed the proportion of glances to each glance location and steering wheel control levels across segments within each time course period (AP engagement, AP disengagement, and AP engaged). The AP engagement and AP disengagement stages were described with respect to three intervals: *before*, *at*, and *after* change in automation state.

RESULTS

Glance location

The percentage of on-road glances was higher before AP engagement (70%) than after (64%; Figure 3, Table 1). The proportion of glances on-road did not decrease gradually. Instead, at the time of AP engagement, there was a sharp, momentary drop in on-road glances to as low as 30% (Figure 3), which increased again in the few seconds that followed. The level of on-road attention was stable throughout the drive with AP engaged (63%; Figure 3). The moment of AP disengagement was characterized by a 12 % increase in the proportion of on-road glances to about 76%, which drivers maintained for several seconds after the transition to manual driving. The sharp drop in on-road glances around AP engagement corresponded to a rapid increase in glances to the instrument cluster as high as 66% (Figure 3). Otherwise, the proportion of glances to the instrument cluster remained low (about 4 – 5%), as was the case around AP disengagement (Figure 3, Table 1).

Glances to the down and center-stack locations accounted for most of the off-road glances when AP was engaged (about 20%; Figure 3, Table 1). The proportion of glances to down and center-stack increased quickly a few seconds after engaging AP and gradually decreased when approaching AP disengagement, with a rapid reduction just before the transition point. At the transition point to manual driving, these glances accounted for only 1%.

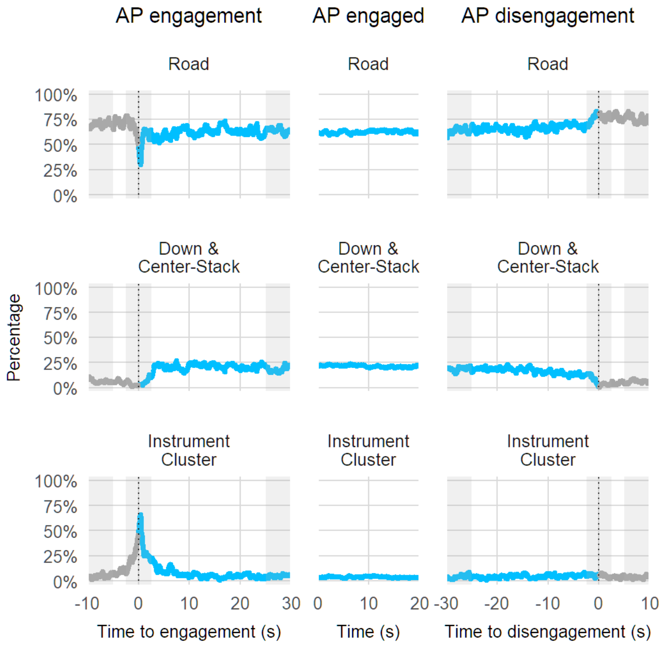

Figure 3. Aggregate percentage of glances at any given time across Autopilot (AP) engagement, AP engaged, and AP disengagement epochs across glance locations. The transition to and from AP is at 0 s, marked with a black dashed line. The shaded bands indicate 5 s intervals that were selected because they were considered an estimate of stable driver behavior during the engagement and disengagement phase or because they highlighted the dynamic behavior during the transition of control.

Table 1. Average percentage (and standard deviation) of glances in Autopilot (AP) engagement, AP engaged, and AP disengagement epochs across locations. For AP engagement epochs, we computed the percent in the -10 s to -5 s interval before the engagement (*before*), the -2.5 s to 2.5 s around the engagement (*at*), and the 25 s to 30 s interval after engagement (*after*). Similarly, for AP disengagement epochs, we computed the percentage in the -30 s to -25 s interval before disengagement (*before*), the -2.5 s to 2.5 s around the disengagement (*at*), and the 5 s to 10 s interval after disengagement (*after*). For AP engaged epochs, the percentage was computed over the full 20 s interval.

	AP engagement			AP engaged	AP disengagement		
	before	at	after		before	at	after
Road	70 (2.2)	62 (11.4)	64 (2.5)	63 (1.2)	64 (2.7)	76 (3.8)	76 (3.4)
Down & Center-stack	7 (1.6)	5 (3.1)	18 (2.8)	21 (1)	18 (1.9)	6 (4.1)	6 (1.3)
Instrument cluster	5 (1.8)	29 (13.8)	5 (1.1)	4 (0.6)	4 (1.8)	5 (1.4)	4 (1.1)
Rearview mirror	3 (1.5)	2 (1)	3 (1.2)	4 (0.5)	5 (1.6)	3 (1.2)	4 (1.2)
Side windows & mirrors	13 (2)	2 (1.5)	7 (1.3)	7 (0.7)	6 (1.7)	7 (2.4)	9 (2.7)
Other	1 (0.7)	0 (0)	1 (0.3)	0 (0.2)	0 (0.5)	1 (0.7)	1 (0.5)

Glances to the side windows and mirrors were most frequent in manual driving (9 – 13%; Table 1). The percentage of glances to these locations decreased right before engagement of AP and increased again soon after AP disengagement. The proportion of the remaining glance categories was generally low and steady in all epochs under analysis.

Steering wheel control level

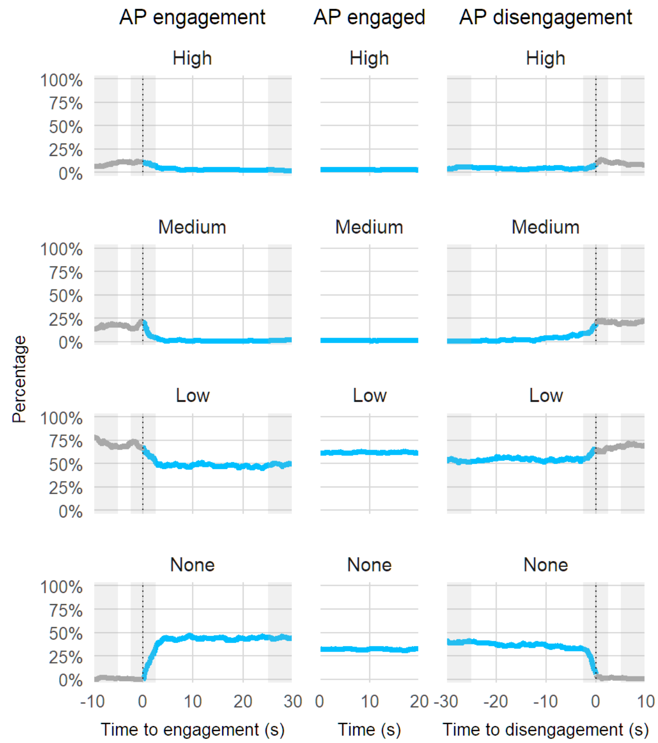

Figure 4. Aaggregated proportion of steering wheel control levels at Autopilot (AP) engagement, AP engaged, and AP disengagement periods. The transition to and from AP is at 0 s, marked with a black dashed line. The shaded bands indicate 5 s intervals for estimating stable driver behavior.

Table 2. Average proportion (and standard deviation) of steering wheel control level in the Autopilot (AP) engagement, AP engaged, and AP disengagement epochs. The *at*, *before*, and *after* periods were calculated as described in Table 1.

	AP engagement			AP engaged	AP disengagement		
	before	at	after		before	at	after
High	8 (1.6)	10 (1.4)	2 (0.5)	3 (0.1)	5 (0.7)	9 (3.4)	9 (0.6)
Medium	17 (1.8)	13 (5.8)	2 (0.4)	1 (0.1)	1 (0)	17 (5.5)	21 (0.9)
Low	72 (3.5)	65 (6.5)	49 (0.9)	62 (0.5)	53 (1.1)	62 (3.7)	70 (1.2)
None	1 (0.7)	9 (11.3)	44 (0.9)	32 (0.5)	40 (0.9)	12 (12.1)	1 (0.4)
Other	2 (0.3)	2 (1.5)	3 (0.1)	2 (0.1)	2 (0.4)	0 (0.2)	0 (0)

In general, drivers maintained a low level of steering control regardless of AP use (Figure 4). During manual driving, the proportion of low level of control was about 70% (Table 2), followed by the medium and high control levels. In the few seconds after AP engagement, drivers further relaxed control of the steering wheel and in many epochs drivers did not grasp the steering wheel at all. Driving with the hands at the medium or high control position was rare. While hands-free driving was practically absent in manual driving, it increased to a value of about 44% immediately after the engagement of AP. The value of hands-free driving found at the end of the AP engagement interval (44%) was higher than the value during the AP engaged epochs (32%), but it was similar to the value at the beginning of the AP disengagement interval (40%). Conversely, the value of low-control was slightly higher during AP engaged events than at the end of AP engagement interval and the beginning of the AP disengagement interval.

DISCUSSION

This paper provides an objective characterization of changes in driver visual attention and steering wheel control when using SAE L2 automation in real-world driving. We observed Tesla owners routinely using their vehicle over a period of months to years. The findings show that under AP, drivers were less attentive to the forward road and exercised lower control of the steering wheel. Changes in visual behavior occurred immediately before and soon after engagement of AP, and the reduction in attention to the forward road was continued until just before AP disengagement, when drivers returned to levels of visual attention to the forward road similar to that observed before engaging AP (Figure 3). While the increase in inattention with AP compared to manual driving is consistent with previous naturalistic, on-road, and test-track studies (Gaspar & Carney, 2019; Llaneras et al., 2013; Morando et al., 2019; Tivesten et al., 2015; Victor et al., 2018), this study is the first to show that the shift in visual attention after AP engagement among a set of experienced AP users is not a gradual process, but rather can be characterized by a sudden decrease in attention to the forward road followed by relatively low and stable levels of attention throughout AP engagement. While one might expect that inattention will gradually increase as time with AP progresses, as documented by Endsley (2017) and similar to the effect of prolonged effort on vigilance (Mackworth, 1948), it seems that drivers have developed over-reliance in AP and divert their attention off-road proximal to engaging AP and throughout its use (Lin et al., 2018).

The shift in drivers' visual attention from the forward road was primarily directed towards the down and center stack glance locations, areas that may be associated with secondary task engagement. This, taken together with the increase in hands-free driving when AP was engaged (Figure 4), may be indicative of secondary task engagement during AP driving (e.g., interactions with handheld devices or with the touchscreen mounted in the center stack). Previous research shows that drivers regulate secondary task engagements based on the perceived stability, predictability, and familiarity of the driving situation (Tivesten & Dozza, 2015). As such, over-estimating the automation's capabilities may lead to inaccurate regulation of secondary task engagement and increased visual inattention. Consequently, drivers may fail to accumulate visual cues (Lamble et al., 1999) and fail to detect system malfunctions that do not generate strong kinesthetic cues (Bianchi Piccinini et al., 2020; Morando et al., 2016), such as lane drifts and failures to detect a vehicle ahead, all of which can result in fatal crashes (National Transportation Safety Board, 2020a, 2020b).

While the time course for most glance locations was similar around the transition to and from AP, we noticed a peak in off-road attention directed to the instrument cluster during the engagement phase that did not appear during AP disengagement (Figure 3). It seems likely that drivers visually checked if AP was available before its engagement, confirmed that the system was in fact active, or adjusted its settings (e.g., speed and time headway of T-ACC). After AP was engaged, the instrument cluster did not attract many glances, suggesting that the system state was transparent enough and did not require extensive visual monitoring.

In-addition to the shift in visual attention, we also find that drivers relaxed direct control of the steering wheel—or drove hands-free—immediately after engaging AP and throughout its use. Drivers start to position their hands back to higher control levels close to the AP disengagement point (Figure 4). While AP is not a hands-free system (Tesla, 2019), it seems that drivers are taking advantage of automation, possibly due to high confidence in the system (Lin et al., 2018). Interestingly, immediately after and throughout AP engagement, we find that the Low and None steering wheel control positions accounted for 93% of steering control behavior. However, throughout the AP engagement period, Low steering wheel control was more common compared to None. This shift from None to Low control behavior is consistent with the occasional nudge to the steering wheel, which is needed to satisfy the torque-based steering wheel driver monitoring system.

CONCLUSIONS

This paper provides new insights on the behavioral changes associated with frequent and prolonged use of AP by Tesla owners in naturalistic driving and it can guide the understanding of systems of similar nature. We find that compared to manual driving, drivers are less engaged in the driving task when using AP. Specifically, drivers direct less attention on-road and reduce their steering wheel control immediately-following AP engagement, and maintain this behavior throughout the use of AP. These findings may indicate complacency and system misuse that can compromise safety. The changes in driver behavior (i.e., shift in attention and steering wheel control) were not gradual but occurred soon after the transition from manual driving to AP. As most of the glances off-road were directed downwards and to the center stack, together with the high prevalence of hands-free driving, it is likely that during these periods drivers where engaged in secondary tasks and this is an area of future analytic focus. Taken together, these findings support the call for improvements in the driver attention management (Mueller et al., 2021; National Transportation Safety Board, 2020c; Reimer, 2020). They also suggest that driver behavior (visual attention and steering wheel control) may be used to predict the timing of automation engagement and disengagement. There are still open questions regarding these findings that require additional research. It is unknown what an optimal level of driver engagement under automation should be. Furthermore, it is unclear if driver engagement should relate to the automation (and other active systems) performance to meet a targeted safety threshold. Automation is being deployed to make driving more comfortable and enable drivers to do other things. Under this context, safety benefits need to be documented to ensure that driver disengagement during automation is not creating unintended risk that exceeds that of a manually controlled conventional vehicle or, perhaps more appropriately, a targeted improvement. The findings in this paper can inform the policy making process and guide the design of safe driver support systems.

ACKNOWLEDGMENTS

Data were drawn from work supported by the Advanced Vehicle Technology (AVT) Consortium. The first author was supported as a postdoctoral associate at the time of this work by the Santos Family Foundation. The co-authors were supported by the AVT Consortium. The views and conclusions expressed are those of the authors and have not been sponsored, approved, or endorsed by the Consortium or Foundation. The authors would like to thank their colleagues at the MIT AgeLab, the members in the AVT Consortium, and four anonymous reviewers for their comments and suggestions on this paper.

REFERENCES

Abraham, H., McAnulty, H., Mehler, B., & Reimer, B. (2017a). Case Study of Today's Automotive Dealerships: Introduction and Delivery of Advanced Driver Assistance Systems. *Transportation research record, 2660*(1), 7-14. doi:10.3141/2660-02

Abraham, H., Seppelt, B., Mehler, B., & Reimer, B. (2017b). *What's in a Name: Vehicle Technology Branding & Consumer Expectations for Automation*. Paper presented at the Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, Oldenburg, Germany. https://doi.org/10.1145/3122986.3123018

Bianchi Piccinini, G., Lehtonen, E., Forcolin, F., Engström, J., Albers, D., Markkula, G., . . . Sandin, J. (2020). How do drivers respond to silent automation failures? Driving simulator study and comparison of computational driver braking models. *Human Factors, 62*(7), 1212-1229.

Consumer Reports. (2020). *Active Driving Assistance Systems: Test Results and Design Recommendations*. Retrieved from https://data.consumerreports.org/wp-content/uploads/2020/11/consumer-reports-active-driving-assistance-systems-november-16-2020.pdf

De Waard, D., Van den Bold, T., & Lewis-Evans, B. (2010). Driver hand position on the steering wheel while merging into motorway traffic. *Transportation Research Part F: Traffic Psychology and Behaviour, 13*(2), 129-140. doi:10.1016/j.trf.2009.12.003

Endsley, M. R. (2017). Autonomous driving systems: A preliminary naturalistic study of the Tesla Model S. *Journal of Cognitive Engineering and Decision Making, 11*(3), 225-238.

Fridman, L., Brown, D. E., Glazer, M., Angell, W., Dodd, S., Jenik, B., . . . Reimer, B. (2019). MIT Advanced Vehicle Technology Study: Large-Scale Naturalistic Driving Study of Driver Behavior and Interaction With Automation. *IEEE Access, 7*, 102021-102038. doi:10.1109/ACCESS.2019.2926040

Gaspar, J., & Carney, C. (2019). The Effect of Partial Automation on Driver Attention: A Naturalistic Driving Study. *Human Factors, 61*(8), 1261-1276. doi:10.1177/0018720819836310

General Motors Corporation Research and Development Center. (2005). *Automotive collision avoidance system Field Operational Test: Final program report (DOT HS 809 886)*. Retrieved from https://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2005/ACAS%20FOT%20Final%20Program%20Report%20DOT%20HS%20809%20886.pdf

Lamble, D., Laakso, M., & Summala, H. (1999). Detection thresholds in car following situations and peripheral vision: Implications for positioning of visually demanding in-car displays. *Ergonomics, 42*(6), 807-815.

Lin, R., Ma, L., & Zhang, W. (2018). An interview study exploring Tesla drivers' behavioural adaptation. *Applied Ergonomics, 72*, 37-47. doi:https://doi.org/10.1016/j.apergo.2018.04.006

Llaneras, R. E., Cannon, B. R., & Green, C. A. (2017). Strategies to assist drivers in remaining attentive while under partially automated driving: Verification of human–machine interface concepts. *Transportation research record, 2663*(1), 20-26.

Llaneras, R. E., Salinger, J., & Green, C. A. (2013, June 17-20). *Human factors issues associated with limited ability autonomous driving systems: Drivers' allocation of visual attention to the forward roadway.* Paper presented at the Seventh International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Bolton Landing, New York, USA.

Mackworth, N. H. (1948). The breakdown of vigilance during prolonged visual search. *Quarterly Journal of Experimental Psychology, 1*(1), 6-21. doi:10.1080/17470214808416738

Malta, L., Aust, M. L., Faber, F., Metz, B., Pierre, G. S., Benmimoun, M., & Schäfer, R. (2012). *EuroFOT Deliverable 6.4 - Final results: Impacts on traffic safety*. Retrieved from http://www.eurofot-ip.eu/

Morando, A., Gershon, P., Mehler, B., & Reimer, B. (2020). *Driver-initiated Tesla Autopilot Disengagements in Naturalistic Driving*. Paper presented at the 12th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '20), Virtual event.

Morando, A., Victor, T., & Dozza, M. (2016). Drivers anticipate lead-vehicle conflicts during automated longitudinal control: Sensory cues capture driver attention and promote appropriate and timely responses. *Accident Analysis & Prevention, 97*, 206-219. doi:10.1016/j.aap.2016.08.025

Morando, A., Victor, T., & Dozza, M. (2019). A Reference Model for Driver Attention in Automation: Glance Behavior Changes During Lateral and Longitudinal Assistance. *IEEE Transactions on Intelligent Transportation Systems, 20*(8), 2999-3009. doi:10.1109/TITS.2018.2870909

Mueller, A. S., Reagan, I. J., & Cicchino, J. B. (2021). Addressing Driver Disengagement and Proper System Use: Human Factors Recommendations for Level 2 Driving Automation Design. *Journal of Cognitive Engineering and Decision Making, 0*(0), 1555343420983126. doi:10.1177/1555343420983126

National Transportation Safety Board. (2020a). *Collision Between a Sport Utility Vehicle Operating With Partial Driving Automation and a Crash Attenuator* (NTSB/HAR-20/01 PB2020-100112). Retrieved from Washington, DC:

National Transportation Safety Board. (2020b). *Collision Between Car Operating with Partial Driving Automation and Truck-Tractor Semitrailer* (NTSB/HAB-20/01). Retrieved from Washington, DC:

National Transportation Safety Board. (2020c). Tesla Crash Investigation Yields 9 NTSB Safety Recommendations. Retrieved from https://www.ntsb.gov/news/press-releases/Pages/NR20200225.aspx

Parasuraman, R., & Riley, V. (1997). Humans and automation: Use, misuse, disuse, abuse. *Human Factors, 39*(2), 230-230.

Reagan, I. J., Cicchino, J. B., & Kidd, D. G. (2020). Driver acceptance of partial automation after a brief exposure. *Transportation Research Part F: Traffic Psychology and Behaviour, 68*, 1-14. doi:https://doi.org/10.1016/j.trf.2019.11.015

Reimer, B. (2020). Should Tesla Take The Initiative To Better Monitor And Manage Driver Behavior With Autopilot? *Forbes*.

SAE. (2018). j3016 - Taxonomy and definitions for terms related to on-road motor vehicle automated driving systems. In: SAE International.

Seppelt, B., Reimer, B., Angell, L., & Seaman, S. (2017). *Considering the Human across Levels of Automation: Implications for Reliance.* Paper presented at the 9th International Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, Equinox, Manchester Village, Vermont.

Seppelt, B., Reimer, B., Russo, L., Mehler, B., Fisher, J., & Friedman, D. (2019). *Consumer Confusion With Levels of Vehicle Automation.* Paper presented at the 10th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design.

Seppelt, B. D., & Victor, T. W. (2016). Potential Solutions to Human Factors Challenges in Road Vehicle Automation. In G. Meyer & S. Beiker (Eds.), *Road Vehicle Automation 3* (pp. 131-148). Cham: Springer International Publishing.

Teoh, E. R. (2020). What's in a name? Drivers' perceptions of the use of five SAE Level 2 driving automation systems. *Journal of Safety Research, 72*, 145-151. doi:https://doi.org/10.1016/j.jsr.2019.11.005

Tesla. (2019). Model S owner's manual. In (2019.16.1.1 ed.).

Tivesten, E., & Dozza, M. (2015). Driving context influences drivers' decision to engage in visual–manual phone tasks: Evidence from a naturalistic driving study. *Journal of Safety Research, 53*, 87-96.

Tivesten, E., Morando, A., & Victor, T. (2015). *The timecourse of driver visual attention in naturalistic driving with adaptive cruise control and forward collision warning.* Paper presented at the Driver distraction and inattention, Sydney, New South Wales.

Victor, T. W., Tivesten, E., Gustavsson, P., Johansson, J., Sangberg, F., & Ljung Aust, M. (2018). Automation Expectation Mismatch: Incorrect Prediction Despite Eyes on Threat and Hands on Wheel. *Human Factors, 60*(8), 1095-1116. doi:10.1177/0018720818788164