The Effect of Augmented Reality Cues on Glance Behavior and Driver-Initiated Takeover on SAE Level 2 Automated-Driving

REMOVED FOR BLIND REVIEW

In the present paper, we present a user study with an advanced-driver assistance system (ADAS) using augmented reality (AR) cues to highlight pedestrians and vehicles when approaching intersections of varying complexity. Our major goal is to understand the relationship between the presence and absence of AR, driver-initiated takeover rates and glance behavior when using a SAE Level 2 autonomous vehicle. Therefore, a user-study with eight participants on a medium-fidelity driving simulator was carried out. Overall, we found that AR cues can provide promising means to increase the system transparency, drivers' situation awareness and trust in the system. Yet, we suggest that the dynamic glance allocation of attention during partially automated vehicles is still challenging for researchers as we still have much to understand and explore when AR cues become a distractor instead of an attention guider.

INTRODUCTION

In recent years we have seen the emergence of more advanced driver-assistance systems (ADAS); especially ones that aim to provide support for SAE Level 2 (L2 - as defined by SAE J3016 [1]) automated-driving (AD) where humans and vehicle share the driving responsibility. If AD systems are successfully implemented on the road in mass scale, they will fundamentally improve the driving experience and afford countless added hours of available time for drivers to devote resources to other valuable occupations.

Because full (or even partial) AD systems represent such a radical departure from traditional driving in terms of the driver-interface relationship, any system that intends to function as an L2 system must overcome a test of good faith from its occupants (as they are placing their wellbeing, at times, in the hands of a machine) and provide its user with an appropriate trust about how it will operate and interact with the world. There are in fact possible outcomes that carry significant risk; insufficient trust may result in frequent (and unneeded) takeovers, however complete over-trust may result in a lapse of monitoring and slower reaction to takeover requests (TORs). While the latter case is limited to AD cases in which continued monitoring is required on the driver's part, the issue remains that much of how drivers perceive risk in the driving scene remains relatively unresearched.

We believe that driver trust and behavior are related to many factors. While we believe the AD performance itself is the most important factor, we hypothesize that user trust of (and altitude towards towards) AD systems is also affected by the task difficulty such as traffic conditions. Thus, understanding the effect of those factors to driver trust is an important issue. To evaluate trust resulting from an AD system, the relationship between road scene complexity and driver trust must be defined and explored. However, the human machine interfaces (HMI) used to mitigate road scene complexity and trust in AD settings should also be considered in order to inform HMI designers in how best to support communication between the autonomous vehicle system and drivers.

Augmented reality (AR) HMIs have the potential to improve communication between drivers and an autonomous vehicle system [2], [3] by visually annotating the scene and drivers' field of view. By using a combination of world-relative and screen-relative cues, an AR HMI could increase system transparency, identify specific road actors that the ADAS can sense, and ultimately keep drivers "in the loop" while also potentially improving their perception of the road scene itself as well as future/planned actions of the AD system.

At a high level our work aims to better understand whether AR can help improve the driving experience in AD settings, by for example, helping drivers feel less stress and anxiety when encountering different traffic scenarios. The paper extends earlier work where we examined drivers' self-reported attitudes and perceptions towards an AD experience in an urban environment both with, and without, an AR HMI under differing traffic conditions [4].

Thus, the purpose of this work is to research how the presence of an AR HMI effects driver-initiated takeover behaviors when approaching intersections of varying complexity, with the assumption that driver-initiated takeover behaviors could be an indirect measure of trust, comfort and general lack of stress/anxiety. Specifically, we are keenly interested in the relationship between the presence and absence of AR and driver-initiated takeover behaviors.

Our hypotheses for this work include:

- **Hypothesis 1:** *The presence of AR will lower driver-initiated takeover rates since drivers will know what their own ego-car can sense, and thus provide greater AD system transparency to drivers.*

We are also interested in understanding how the presence of AR graphics affects drivers' glance behavior (as compared to no AR), and whether or not these changes in glance behavior are related to driver-initiated takeover rates. As such, we further posit that:

- **Hypothesis 2:** *The presence of AR will capture drivers' visual attention resulting in longer glances (and glances to fewer areas of interest). However, these longer glances do not necessarily mean that the driver is less safe, since these glances may be informing drivers about ego car knowledge and plans as they approach intersections.*

A contribution of this work includes a deeper understanding of the relationships between AR, glance behavior and driver-initiated takeover rates in SAE L2 driving settings. To the best of our knowledge, we know of no other study that employs AR in takeover scenarios where the takeover is not scheduled or announced.

METHODS

Participants

We recruited eight licensed drivers aged from 18 to 30 years (μ=23.56 years, σ=6.65). All participants were screened for normal or corrected to normal vision and were required to have a valid driver's license for more than two years and drive more than 5000 miles per year. No participant had previous experience with neither AR-based interfaces nor advanced driver-assistance systems.

Equipment

We conducted this study in a fixed-base, medium-fidelity driving simulator at [HIDDEN FOR REVIEW]. This simulator is composed of the front half of a [HIDDEN FOR REVIEW] cab fitted with a curved projection with 94 degrees of view, and both side and rear-view mirrors. The simulator also contains a 7'' monitor mounted directly behind the steering wheel to convey vehicle speed information [5]. The simulation forward visual scene was projected in front of the driver via an Epson PowerLite Pro projector, cast at approximately 3 meters in front of the driver's eye line. The virtual scene, experimental computing systems, and cab controls were integrated allowing participants to experience an L2 vehicle and still take over manual control if desired. All simulated driving environments were rendered using Unreal Engine 4.18 which enabled detailed visual effects such as shadow rendering, post-processing, ambient vegetation, and light scattering in high definition; AR cues were rendered using Unity. A scene recorder plugin communicated with Unreal to track objects in the virtual scene to support Unity in rendering conformal AR cues in real-time. For this study, participants wore Tobii Pro Glasses 2 eye-tracking system equipped with audio and video recording to track gaze behavior.

Experimental Design

We employed a three-factor repeated measures experimental design (2x2x2), such that participants completed driving tasks under each of eight driving conditions: 2 levels of AR presentation presence (*ON* and *OFF*), 2 levels of traffic density (*low (LT)* and *heavy (HT)*) and 2 levels of traffic type (*cars only* (CO) and *cars + pedestrians (CP)*). Each participant experienced three intersection events for each experimental condition, for a total of 24 events per participant. We used a balanced Latin Square design to counterbalance the presentation order of conditions within participants (see [4] for more details).

Intersections Design

Using iterative designing that examined limitations of our simulated road geometry, computing power needed to render other cars and pedestrians, and our simulator's projector field of view, we created four final intersection designs with differing traffic density and actors: (1) *Heavy Traffic, Cars Only* (HT + CO) – total of eight vehicle actors, three cars from each side of road cross traffic and two cars oncoming; (2) *Light Traffic, Cars Only* (LT + CO) - total of four vehicle actors, one car from each side of road cross traffic and two oncoming; (3) *Heavy Traffic, Cars + Pedestrians* (HT + CP) – total of four vehicle actors and eight pedestrians, two cars from each side of road cross traffic (no oncoming) and pedestrians at randomized direction but positioned to avoid collision; and; (4) *Light Traffic, Cars + Pedestrians* (LT + CP) – total of two vehicle actors and four pedestrians, one car from each side of road cross traffic (no oncoming) pedestrians at randomized direction but positioned to avoid collision.

AR Graphical Cue Design

Our AR cues were conformal bounding boxes creating a cubic region surrounding a specific actor; blue bounding boxes to highlight pedestrians, red for vehicles (Figure 1). Since this work did not aim to investigate different AR cue designs (as done in [4]) we instead opted for a cueing style commonly used in computer vision applications, and which adequately satisfies the first stage of Endsley's three-stage model of situational awareness (i.e. *perception*, comprehension, projection) [6].

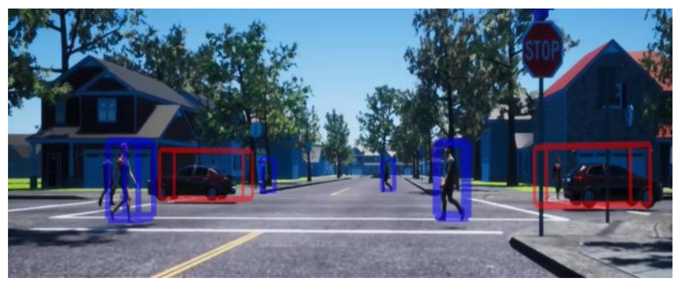

Figure 1: AR cues conformal bounding boxes concept used in this work: blue bounding boxes to highlight pedestrians, red for vehicles.

The AD System

To accurately and realistically simulate a working AD system, we used the Wizard of Oz method which helped us to reduce the complexity to program complicated vehicle behavior, as previously done in similar work [7]. We designed a recording software feature in which one expert driver researcher (to ensure consistency) drove the simulated vehicle though each route, while software logged all steering and pedal data to an AD drive file that we later used to automate the ego-car movements. When the simulator detected any pedal or steering input from the participant (indicating a driver-initiated takeover action), our novel AD system relieved control of the ego-car to the driver. After four seconds of no changes in manual driving input, the AD system resumed control and the vehicle was directed back to the recorded route through nearest estimated simple curving. We logged detailed ego-car dynamics during driver-initiated takeover and manual driving to assist in subsequent analysis.

Procedure

Upon arrival at the lab, participants consented to the study using IRB-approved processes. We briefly explained the study goals and procedures and allowed participants to familiarize themselves with the simulator cab and functions. After equipping participants with Tobii Pro Glasses 2 eye-tracking system, participants completed a practice driving through the simulated urban environment. During this familiarization drive, we instructed them to monitor the autonomous vehicle system and if they felt the need to pull over or stop the vehicle, they should do so by engaging the brake and steering to stop. We did not tell participants that the drive would be 100% safe. We instructed participants to abstain from taking over further than was needed to maintain perceived safety and to allow the AD system to resume once they felt the situation was safe by releasing the brake and steering wheel. Upon completion participants signed a post-trial consent form and were compensated $10.

RESULTS

Driver-Initiated Takeover

Takeover Rates

A total of 192 events took place in this study (8 participants * 8 experimental conditions * 3 events in each condition) in which 53 events (27.60%) corresponded to a driver-initiated takeover event. Overall, we found that driver-initiated takeover occurrences were generally higher during AR OFF conditions (64.15%), compared to AR ON condition (35.85%). Remember that takeover was optional as we neither told participants that the drive would be 100% safe nor presented any visual/auditory takeover requests (TOR) signal.

Takeover Timing (reaction time)

In this study, intersection actors (vehicles and pedestrians) began moving at a time to collision (TTC)=5s (or 56 meters from the intersection stop line) from when the ego-car arrived at a specific intersection. Overall, drivers took 3.806 seconds (σ=0.939) to initiate takeover action. ANOVA results revealed a main effect of AR presence ($F = 6.37, p<0.015$) and traffic type ($F = 7.60, p<0.008$) on takeover reaction time. Tukey's post-hoc findings showed that participants took longer to initiate takeovers with no AR cues (μ=4.44 seconds) and cars only traffic type (μ=4.43 seconds) compared to when AR cues were ON (μ=3.85 seconds) and **mixed traffic conditions** (μ=3.86 seconds).

Takeover Performance

ANOVA results showed a main effect of AR presence ($F = 5.42, p<0.024$) on braking deceleration. In this case, Tukey's post-hoc findings revealed that braking deceleration is generally higher when AR cues are ON (μ=1.257 g) compared to when AR cues are OFF (μ=1.076 g). Additionally, participants presented higher variability of braking deceleration with no AR cues.

When analyzing participants' stop gap during takeover trials, we found a main effect of AR presence ($F = 7.55, p<0.009$), and traffic type ($F = 8.05, p<0.007$). Tukey's post-hoc findings showed that participants stopped further from the stop line when AR was ON (μ=16.92 meters) compared to when AR was OFF (μ=11.50 meters) Likewise, stop gap is higher with mixed traffic (μ=16.69 meters) compared to cars only (μ=11.73 meters). Additionally, we also found an interaction effect on stop gap between traffic type and traffic size conditions ($F = 15.46, p<0.000$). Further, according to the Pearson's correlation coefficient, participants' stop gap is strongly positively correlated to their breaking deceleration level (*Pearson* $=0.540, p<0.000$). However, further examination showed that correlation is only significant when AR is OFF (*Pearson* $=0.612, p<0.000$), compared to when AR is ON (*Pearson* $-0.005, p<0.985$).

Glance Behavior

Total Number of AOIs Scanned

We categorized drivers' glances into 52 AOIs, but when evaluating the total number of AOIs scanned during trials, we found that a maximum of 33 AOIs (63.46 % of 52 total AOIs) had been scanned. Further, we found that participants scanned a higher number of AOIs in no takeover trials *(μ=32.5, n=32 AR ON, n=33 AR OFF)* relative to trials where takeover took place *(μ=11, n=10 AR ON, n=12 AR OFF).*

Number of Glances per Event Before Initiating Takeover

In takeover events, we found that on average participants glanced 3.765 times ($\mu=0.366, min=1, max=10$) towards different AOIs before initiating takeover action when no AR cues were presented. On the other hand, when AR cues were present, participants glanced an average of 3.105 times *($\mu=0.418, min=1, max=7$)* towards different AOIs. However, Kruskal-Wallis test revealed that this difference is not statistically significant.

Total Number of Glances

We measured the total number of glances by AOI in percentage terms. Overall, we found that in takeover events, the distribution of the total number of glances is fairly similar in both AR conditions, but AR ON presents a trend of more glances towards the same AOIs. Also, the road outgoing AOI resulted in the highest total number of glances in both AR ON (47.46%) and AR OFF (42.97%) conditions, followed by road oncoming for both AR ON (10.17%) and AR OFF (10.16%) conditions.

Likewise, in trials with no takeover event, the distribution of the total number of glances is fairly similar in the presence and absence of AR cues. Again, the road outgoing AOI resulted in the highest number of total glances in both AR ON (33.98%) and AR OFF (36.41%) conditions. Interestingly, we found that there is a trend in which when AR was ON, participants glanced more times towards pedestrians compared to AR OFF.

Maximum Glance Duration

In takeover trials, our results showed that the maximum duration of a glance was found towards the road outgoing AOI (5286 msec) during the AR OFF condition, and towards the pedestrian crosswalk AOI (3958 msec) during the AR ON condition. In situations where takeover did not occur, maximum glance durations were found towards the road outgoing AOI for both the presence (14361 msec) and absence (5617 msec) of AR cues.

Mean Glance Duration

When analyzing mean glance duration in takeover trials, we did not find a main effect of AR presence ($F = 0.08, p<0.773$), traffic size (*F =0.01, p<0.924*) or traffic type (*F =7.60, p<0.472*). However, when analyzing mean glance durations towards different AOIs, we found a trend in which AR ON glances presented shorter durations when compared to AR OFF glances. Additionally, maximum mean glance durations were found towards the pedestrian crosswalk front AOI in both AR ON (2552.27 msec) and AR OFF (1733.2 msec) conditions.

When evaluating mean glance durations in cases where takeover did not occur, we found a main random effect of participant (*Z =1.75, p<0.04*), and a main effect of traffic type (*F =14.00, p<0.000).* This significant random effect indicates that mean glance durations differ among participants. Tukey's post-hoc findings have shown that participants presented longer mean glance durations while experiencing "cars only" conditions (μ=809.89msec) compared to the mixed traffic conditions (μ=675.46msec). We also found a trend in which the AR ON condition presented longer glances compared to AR OFF conditions.

DISCUSSION

In this study, we found evidence that the presence of AR may reduce the number of driver-initiated takeover actions (35.85%) compared to when no AR cues are presented to drivers (64.15%). Therefore, we fail to reject hypothesis 1: *"The presence of AR will lower driver-initiated takeover rates.* We believe that the number of driver-initiated takeover actions is reduced in the presence of augmented reality cues for two main reasons: (1) the perceived trustworthiness of the automated system is likely increased by making the vehicle detection capabilities more salient, and (2) AR cues increase drivers' understanding of how the automation operates (system transparency), and so drivers may trust more in the system. In fact, our finding is consistent with previously conducted user-studies that show that more trust in the AD system may be gained when knowledge of vehicle detection capabilities are provided using AR cues [4], [8], [9].

Also, we found that drivers took longer to decide to initiate takeover when no AR cues are available to them and when traffic consists of cars only, meaning that drivers may interpret the traffic situation differently (as compared to mixed-traffic cases). It is most likely that when "driving" our L2 vehicle, drivers' attention was "out-of-the-loop" and thus, AR has the potential to help redirect drivers' attention back into-the-loop so that they can take over the driving task sooner if needed. Likewise, this reduction in time to initiate takeover action in the presence of AR suggests that AR cueing could help in the *perception* level of situation awareness, as drivers perceived the road actors much sooner and acted more quickly when they felt a takeover action was needed. This finding is consistent with other studies that have shown drivers with AR cues can achieve higher perception levels for hazard detection [10], [11], and can respond more quickly to the presence of road hazards [12].

In addition, we have found that takeover driving behavior (in terms of braking deceleration and stop gap) changes with the presence of AR cueing. Although we found that drivers may have more severe braking with AR, braking behavior appears to be more uniform (with less variability in terms of braking deceleration). Another important finding is that AR cues induced safer braking in terms of stop gap, as drivers stopped further from intersection stop line as compared to when no AR cue was present. Thus, we suggest that not only does AR help reduce driver-initiated takeovers when drivers may be unsure, but also the quality of takeover (in terms of driving performance) is better when the driver-initiated takeovers do occur when AR is present.

An objective of this work was to better understand if AR cues change drivers' glance behavior as a measure of visual attention. Further, we wanted to explore how the presence of AR affects driver-initiated takeover rates when approaching intersections. We expected that by exploring glance patterns and trends we could start to think about driver-initiated takeover as an indirect measure of trust in the ADAS system and further explore the relationship between takeover and drivers' visual attention. Overall, in circumstances where takeover occurred, we found that the presence of AR cues is related to: (1) lower total number of AOIs scanned, (2) lower number of glances before deciding to undertake takeover action, and (3) glances of shorter duration. Surprisingly, in situations where takeover did not occur, the presence of AR cues was related to a greater number of AOIs scanned and glances of longer duration. Here, we observed that when AR is present, drivers' glance behavior dynamically changes depending on the driving situation (takeover vs non-takeover). Perhaps a system that alerts drivers to pedestrians and vehicles has the potential to inform and alert drivers of road hazards, but also become a distracting factor (as shown by longer glances in situations of no takeover occurrences). This switch phenomenon we observed suggests that there may be a perceptual threshold for the usefulness of AR cueing as a visual attention guider. A such, a system that is capable of dynamically alerting drivers of road hazards only when it detects that the driver is not already aware of them merits further research. Recall that our hypothesis 2 is: "*the presence of AR will capture drivers' visual attention resulting in longer glances (and glances to fewer areas of interest)."* However, we found mixed results that partially support hypothesis 2. In takeover situations, AR presence resulted in shorter glances and glances to fewer areas of interest. On the other hand, in non-takeover situations, AR presence resulted in longer glances and glances to more areas of interest, perhaps indicating that drivers may have higher levels of trust, comfort, and general lack of stress/anxiety with the ADAS system in this situation, as evidenced by [4] and [3]. However, it could also be that drivers just need more time to make sense of the environment, given that there were no obvious hazards that require them to intervene [see [13] for a discussion about "wait and see behavior" with autonomous driving and takeover].

Also, we found that our ADAS system resulted in many maximum glance durations greater than 4 seconds in both presence and absence of AR cues. Driver distraction is not a new safety problem, and these glances are much longer than what is considered dangerous in manual driving (e.g., over 1.7 to 2.0 seconds; [14]). Although there is no safe glance threshold for automated or vehicles with AR cueing [15], this result still suggests that partial automation has the potential to contribute to driver underload associated with low levels of engagement with the driving environment. As driving systems become more automated, driving demands are reduced, which on the one hand can be helpful in complex and challenging driving situations. However, underload due to vehicle automation is linked to a loss of situation awareness when the driver is disengaged from the driving task [16]. When analyzing situations when takeover did not occur, we found that the presence of AR led to a maximum glance duration towards the road outgoing AOI almost 8 seconds greater than the maximum glance duration towards the same AOI in the absence of AR cues. This finding could indicate that the concept of providing AR cues is interesting and novel to drivers and directs their attention towards the road even when system is trusted by them.

In partially automated vehicles, drivers must monitor the driving task and be prepared to interfere when necessary [17]. As a result, these systems may pose new challenges regarding visual attention and vigilance in monitoring the roadway. Previous research has shown that prolonged and monotonous automated drives have the potential to result in a decrement of the useful field of view [18]. As a result, drivers tend to focus more on a small area of the forward road rather than actively addressing potential peripheral hazards [19]. Although we did not evaluate drivers' peripheral target detection ability, we observed that in both AR presence conditions where no takeover occurred, drivers glanced towards 63% of our predefined areas of interest (a maximum of 33 scanned AOIs out of a total of 52). There is, therefore, a chance that this vigilance decrement phenomenon could have caused drivers to miss important road elements that would otherwise have been detected in manual driving contexts. This finding alone merits further investigation. Finally, we also found that, in the presence of AR cues, drivers tend to glance more towards pedestrians than vehicles. This finding is consistent with previous work in which AR cuing could enhance situation awareness for detecting pedestrians, but not vehicles during a simulator experiment [11].

CONCLUSION

In the present paper, we performed a user study to examine how an advanced driving assistance system for L2 AD vehicles -employing conformal AR to highlight pedestrians (using blue AR cues) and vehicles (using red AR cues)- influences driver-initiated takeover and glance behavior. Overall, we showed that when AR is not present, driver gaze does not delineate or vary much as the intersection density and actors (pedestrians and vehicles) change. But when AR is present, suddenly drivers change their gaze patterns depending on the nature of the road scene. Therefore, we suggest that unique AR highlighting for different road scene objects directly impacts drivers' visual attention. Furthermore, although we found that AR cues can provide promising means to improve driver safety, potentially reducing time-to-takeover and increasing the probability of hazard detection, we suggest that the dynamic allocation of attention during partially automated vehicles is still challenging for researchers. Therefore, we still have much to understand and explore to better understand under what contexts AR cues become a liability (e.g., a distraction) as opposed to a benefit (e.g., to guide attention) in L2 AD vehicles.

REFERENCES

[1] SAE, "J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems - SAE International," 2014. Accessed: Mar. 02, 2021. [Online]. Available: https://www.sae.org/standards/content/j3016_201401/.

[2] A. Kunze, S. J. Summerskill, R. Marshall, and A. J. Filtness, "Augmented reality displays for communicating uncertainty information in automated driving," in *Proceedings - 10th International ACM Conference on Automotive User Interfaces and Interactive Vehicular Applications, AutomotiveUI 2018*, Sep. 2018, pp. 164–175, doi: 10.1145/3239060.3239074.

[3] M. Ebnali, R. Fathi, R. Lamb, S. Pourfalatoun, and S. Motamedi, "Using Augmented Holographic UIs to Communicate Automation Reliability in Partially Automated Driving," 2020.

[4] X. Wu, C. Merenda, T. Misu, K. Tanous, C. Suga, and J. L. Gabbard, "Drivers ' Attitudes and Perceptions towards A Driving Automation System with Augmented Reality Human-Machine Interfaces," 2020.

[5] J. L. Gabbard, B. Jonas, M. Smith, K. Tanous, and H. Kim, "AR DriveSim: An Immersive Driving Simulator for Augmented Reality Head-Up Display Research," *Front. Robot. AI | www.frontiersin.org*, vol. 6, p. 98, 2019, doi: 10.3389/frobt.2019.00098.

[6] M. R. Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems," 1995. Accessed: Feb. 14, 2019. [Online]. Available: https://journals.sagepub.com/doi/pdf/10.1518/001872095779049543.

[7] T. Fuest, L. Michalowski, L. Traris, H. Bellem, and K. Bengler, "Using the Driving Behavior of an Automated Vehicle to Communicate Intentions - A Wizard of Oz Study," in *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, Dec. 2018, vol. 2018-Novem, pp. 3596–3601, doi: 10.1109/ITSC.2018.8569486.

[8] P. Lindemann, T. Y. Lee, and G. Rigoll, "An Explanatory Windshield Display Interface with Augmented Reality Elements for Urban Autonomous Driving," in *Adjunct Proceedings - 2018 IEEE International Symposium on Mixed and Augmented Reality, ISMAR-Adjunct 2018*, Jul. 2018, pp. 36–37, doi: 10.1109/ISMAR-Adjunct.2018.00027.

[9] M. Dikmen, "Investigating Driver Experience and Augmented Reality Head-Up Displays in Autonomous Vehicles," 2017.

[10] M. T. Phan, I. Thouvenin, and V. Frémont, "Enhancing the driver awareness of pedestrian using augmented reality cues," in *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, Dec. 2016, pp. 1298–1304, doi: 10.1109/ITSC.2016.7795724.

[11] M. L. Rusch *et al.*, "Directing driver attention with augmented reality cues," *Transp. Res. Part F Traffic Psychol. Behav.*, vol. 16, pp. 127–137, Jan. 2013, doi: 10.1016/j.trf.2012.08.007.

[12] M. C. Schall *et al.*, "Augmented reality cues and elderly driver hazard perception," *Hum. Factors*, vol. 55, no. 3, pp. 643–658, Jun. 2013, doi: 10.1177/0018720812462029.

[13] L. Tijerina, M. Blommer, R. Curry, R. Swaminathan, D. S. Kochhar, and W. Talamonti, "An Exploratory Study of Driver Response to Reduced System Confidence Notifications in Automated Driving," *IEEE Trans. Intell. Veh.*, vol. 1, no. 4, pp. 325–334, Dec. 2016, doi: 10.1109/TIV.2017.2691158.

[14] T. a. Dingus *et al.*, "The 100-Car naturalistic driving study phase II – Results of the 100-Car field experiment," 2006. doi: DOT HS 810 593.

[15] N. De Oliveira Faria, "Evaluating Automotive Augmented Reality Head-up Display Effects on Driver Performance and Distraction," in *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, 2020, pp. 553–554, doi: 10.1109/VRW50115.2020.00125.

[16] J. D. Lee, C. D. Wickens, Y. Liu, and L. N. Boyle, *Designing for people : an introduction to human factors engineering*. .

[17] J. Östlund *et al.*, *Title HASTE Deliverable 2 HMI and Safety-Related Driver Performance*. 2004.

[18] J. Rogé, L. Kielbasa, and A. Muzet, "Deformation of the useful visual field with state of vigilance, task priority, and central task complexity," *Percept. Mot. Skills*, vol. 95, no. 1, pp. 118–130, Aug. 2002, doi: 10.2466/pms.2002.95.1.118.

[19] M. Körber, A. Cingel, M. Zimmermann, and K. Bengler, "Vigilance Decrement and Passive Fatigue Caused by Monotony in Automated Driving," *Procedia Manuf.*, vol. 3, pp. 2403–2409, Jan. 2015, doi: 10.1016/j.promfg.2015.07.499.