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Changes in driver glance behavior when using a system that automates steering to perform a low-speed parallel parking maneuver

David G. Kidd [a,*], Bryan Reimer [b], Jonathan Dobres [c], Bruce Mehler [b]

[a] *Insurance Institute for Highway Safety, 1005 N. Glebe Road, Arlington, VA 22201, United States*
[b] *MIT AgeLab & New England University Transportation Center, 77 Massachusetts Avenue, E40-291, Cambridge, MA 02139, United States*
[c] *Formerly of the MIT AgeLab & New England University Transportation Center, 77 Massachusetts Avenue, E40-291, Cambridge, MA 02139, United States*

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A B S T R A C T

Drivers adapt their glance behavior when using automation, which may detract attention from their surroundings. Glance behavior during parallel parking maneuvers performed with and without automated steering was compared. Drivers directed a smaller proportion of their glances toward the parking space and spent less time looking at it when using automation than when not using automation. The proportion of glances and time spent looking at the instrument cluster containing information from the automation increased significantly. Drivers also spent a significantly larger proportion of time looking at the instrument cluster and a smaller proportion looking forward and rearward when using automation while approaching a parking space. The system selected the parking space in the approach phase, which may have drawn attention to the instrument cluster. In conclusion, when using automated steering during parallel parking drivers monitored their surroundings less and looked at system displays more presumably to supervise the automation. The safety implications of these changes in glance behavior should be explored in future research.

1. Introduction

Newer parking assistance systems use vehicle-based sensors to identify an open parking space and automatically control vehicle steering and sometimes the throttle and brake to precisely maneuver the vehicle into the identified space. Although these systems use vehicle-based sensors to detect surrounding objects and guide the vehicle into an open parking space, the driver remains responsible for monitoring the vehicle surroundings, detecting objects and events, and responding appropriately. The AutoPark system equipped to the 2018 Tesla Model S, for example, controls vehicle steering, throttle, and braking to maneuver the vehicle on a predetermined path into a detected available space, but, as described in the owner's manual, the system may not always detect objects in parking spaces and the driver must be prepared to apply the brakes to avoid vehicles, pedestrians, or objects (Tesla, 2018, p. 86). Whether drivers monitor their surroundings the same way when they are using automation to park as when they are parking unassisted is an open question.

* Corresponding author.
E-mail address: dkidd@iihs.org (D.G. Kidd).

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Technologies that augment the way information is acquired when performing the driving task can change visual scanning behavior. For instance, rearview cameras and parking sensors enhance visibility and detection in areas around the vehicle that are not visible using mirrors or glances through windows. Kidd and McCartt (2016) found that drivers performing low-speed parking maneuvers who used cameras, parking sensors, or both looked rearward over their shoulders for less time than drivers who did not use the technologies. Other studies have reported similar results (e.g., Kim, Rauschenberger, Heckman, Young, & Langem, 2012; McLaughlin, Hankey, Green, & Kiefer, 2003; Rudin-Brown, Burns, Hagen, Roberts, & Scipione, 2012).

There are several reasons to expect that parking assistance systems that steer the vehicle during a low-speed parking maneuver also would change driver glance behavior. Sequences of eye movements that make up glance behavior are tailored to current driving demands and where the driver needs to gather information to drive (Land & Lee, 1994; Land, 2006; Mourant & Rockwell, 1970; Shinar, 2008). Automating vehicle control can reduce driving demand (de Winter, Happee, Martens, & Stanton, 2014; Ma & Kaber, 2005; Stanton & Young, 2005) and also, in the case of lateral vehicle control, lead drivers to look at areas in the lateral direction less since they are no longer performing this aspect of the driving task.

Humans can sometimes rely too much on automation or pay less attention to the information automation is using to perform a task (Parasuraman & Wickens, 2008). In driving, past research has found that drivers using adaptive cruise control look at the forward roadway less (Reimer, Mehler, Dobres, & Coughlin, 2015). Instead, drivers redirect their gaze to other parts of the roadway (Tivesten, Morando, & Victor, 2015) or even to secondary activities unrelated to driving (Malta, Aust, & Faber, 2012). Similarly, drivers using parking assistance systems that control vehicle steering may withdraw attention from areas in the lateral direction and focus more on areas in the longitudinal direction to better support throttle and brake control or elsewhere.

Finally, drivers using automation must adapt their glance behavior to supervise it. Information about the status and operation of driving automation systems are typically found in in-vehicle displays. Information about adaptive cruise control systems is typically located in the instrument cluster. Tivesten et al. (2015) found that drivers looked at the instrument cluster more when using adaptive cruise control than when not using the feature.

Only one published study was identified that has examined glance behavior when drivers were using driving automation technology to perform a low-speed parking maneuver. Totzke (2010) examined the frequency of driver glances to different fields of view when using driving automation that controlled vehicle steering to reverse into a parking spot and when not using it. When using the automation, drivers made 22% of their glances to a center console display that contained system information, but only 1% of driver glances were to this area when the system was not being used. Drivers also made fewer glances through the rear window when using a parking assistance system that steered the vehicle. However, the study did not report any statistical comparisons of these data. Furthermore, glance behavior was characterized as a function of the fields of view that drivers used (e.g., mirrors, windows) rather than the areas around the vehicle that were being monitored. Thus, it is unclear how using driving automation during low-speed parking maneuvers affected the way drivers monitored and cross-checked information relevant to steering the vehicle.

The purpose of this study was to examine how using a parking assistance system that steered the vehicle during a parallel parking maneuver influenced driver glance behavior to different areas around the vehicle. Glance behavior was expected to be significantly different when drivers used the automation when parallel parking, compared with when drivers only used a rearview camera and parking sensor system. Drivers were expected to glance more frequently at the instrument cluster and spend significantly more time looking at it when using automation than when not using it in an effort to monitor system information and status. Additionally, drivers were expected to glance toward the right and left of the vehicle less frequently and spend less time looking at these areas when using the automation than when not using it. Instead, they were expected to redirect their attention to areas in front of and behind the vehicle to support longitudinal vehicle control.

2. Method

2.1. Participants

Data from 42 drivers who participated in a study evaluating driver stress and driving performance during the use of a semi-automated parallel parking system (Reimer, Mehler, & Coughlin, 2016) were used in this study. An equal number of men and women were recruited in three age groups (20s, 40s, 60s) from the greater Boston area using online, print advertisements, or referrals. Participants were in self-reported good health and were not taking medications that caused drowsiness or altered their psychological state (e.g., antipsychotics, antianxiety). Each driver had a valid driver's license for three or more years and did not report having a crash in the past year.

The current study focused on the frequency of glances toward different locations inside and outside the vehicle and the amount of time that drivers spent looking at each location when drivers parallel parked without and with the Lincoln Active Park Assist™ system, which automatically controlled vehicle steering. The timing and location of eye glances were coded from video recordings of the drivers' faces. The quality of video recordings from 11 of the original 42 participants was inadequate for coding eye glances. Glasses or poor lighting in these recordings resulted in an inconsistent, unclear picture of the driver's face. The final sample of 31 participants included 11 (six women) drivers in their 20s, 12 (six women) in their 40s, and 8 (three women) in their 60s.