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Performing a secondary task while driving impairs various performance measures, including speed control. Distraction is associated with reductions in driving speed; however, this is often based on global measures of performance, such as course completion time or mean speed. This study investigated how a secondary task affected granular speed variation. Participants (N=16, ages 18-43) performed a secondary task of mentally subtracting pairs of numbers while negotiating a simulated road course. Various driving performance measures were obtained but only results for longitudinal velocity are reported. The results reveal that drivers exhibited significant increases and decreases (>2+/- SD) in vehicle speed under distraction, with participants showing a stronger tendency to decrease their speed (60% of the observed speed violations). This may explain why global measures of driving speed under distraction reveal a slowing down. These results may increase our understanding of the nuanced effects of distraction on driving and be useful for predicting/diagnosing distracted driving behavior.

INTRODUCTION

According to a survey conducted in 2019 by the AAA Foundation for Traffic Safety, roughly 43% of respondents noted that they had interacted with a cell phone at least once while driving within the past 30 days, despite nearly 75% of respondents noting that they deemed texting and driving as “extremely dangerous.” A diary study conducted in 2020 that followed participants’ driving behavior over four weeks found 211 instances of drivers directly engaging with technology while driving, and 84% of these device interactions were initiated by the driver (Parnel, Rand, & Plant, 2020). With the knowledge that drivers are going to engage in distracting behaviors, and that these behaviors can result in tragedy and accident-related costs, automotive companies and public safety officials have a vested interest in exploring the effects of distraction on driving.

Overall, much of the scientific literature commonly describes the behavioral effect of distraction as a decrease in speed (Rakauskas, Gugerty, & Ward, 2004; Oviedo-Trespalacios, Haque, King, & Washington, 2017b). However, other studies, such as Fitch and colleagues (2014) found that drivers increased their speed while driving distractedly. Additionally, Oviedo-Trespalacios and colleagues (2017a) state that distracted drivers drive at faster speeds the more experienced they are.

It is apparent that there is inconsistency regarding the type of behavior that distraction results in. However, many studies only report global performance measures, such as average velocity or mean time to complete a course, when evaluating distracted driving (Donohue, James, Eslick, & Mitroff, 2012). These summary statistics may mask how drivers respond to secondary task demands over shorter time scales and how this variation might be reflected in vehicle speed control.

For this study, distraction was defined as any event or behavior that drew cognitive, visual, and physical attention away from the primary task, which was driving in a simulator. Participants engaged with a cell phone in a secondary task that required them to read, evaluate, and respond to text messages that consisted of subtraction equations. We investigated how performance of the secondary task affected longitudinal velocity compared to control road segments where the participants only drove. It was hypothesized that distraction would lead to larger variation in speed control relative to the control road segments, as the participants’ attention was focused on the secondary task, leaving fewer attentional resources for them to monitor their speed.

METHOD

Participants

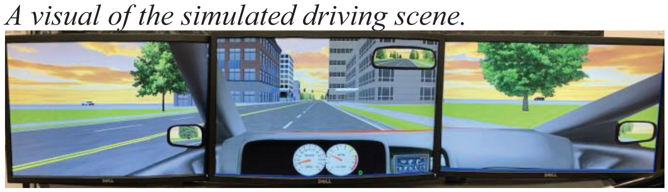
Seventeen individuals participated in the study. One participant’s data was not included in the analysis due to a failure to follow instructions. Of the 16 remaining participants, there were 6 males and 10 females. Their ages ranged from 18 to 43 years (M = 24.05; SD = 6.38). Driving experience ranged from 0.5 years to 27 years (M = 6.6; SD = 6.1). All participants had normal visual acuity (at least 20/20 corrected or natural) and color vision as assessed using the Snellen Visual Acuity Chart and the Ishihara Color Test, respectively. They all were right-handed and had a valid U.S. driver's license.

Materials

The driving task was performed using a STISIM 3 driving simulator. The setup consisted of an adjustable driver’s seat, a Logitech G29 steering wheel and accelerator/brake pedal set, and three monitors to view the driving scene. The simulated course included various stop lights, curves, and hills in addition to randomly-placed buildings, trees, road signs/billboards, and oncoming traffic to increase the realism of the driving task. The entire simulation consisted of a two-way, two-lane track with no same-direction traffic. Speakers were used to provide auditory feedback, such as engine noise. An iPhone XS was mounted to the right of the driver for participants to engage with during the secondary texting task. Figure 1 shows the simulator set up and Figure 2 displays an example of the simulated driving scene displayed by the three monitors.

Figure 1
An image of the simulator, including chair, screens, and driving equipment.

Figure 2
A visual of the simulated driving scene.



Procedure

Driving task. Participants drove one practice trial of a 25,000 ft (≈ 4.7 miles) road to become familiar and comfortable with the controls of the driving simulator. Within the practice course, participants practiced the secondary texting task from 10,000 ft to 14,000 ft while driving. For the study, participants drove an 87,000 ft (≈16.5 mi) road course and engaged with the secondary task at predetermined points in the course. Each section where the participants were expected to text, considered a distraction segment, consisted of a straight road with no oncoming traffic. Participants were told to follow all road rules and instructed to stay in the right lane for the duration of the drive. Posted speed limit signs displayed 45 mph during the secondary task portions of the study. Otherwise, speed limits varied between 35 and 45 mph during the drive.

Secondary task. Texts were sent to the participant during six distraction segments spaced throughout the course. The segments were 4,000 ft (≈0.75 mi) in length. The texts consisted of two-digit subtraction equations (e.g., 54 - 16). A second researcher sent an equation to the iPhone mounted to the right of the participant, who then responded via text. The next subtraction equation was sent immediately after each response. This continued until each distraction segment of the drive was complete. The number of correct and incorrect subtraction answers were collected and were used to evaluate the participant’s level of engagement with the secondary task.

Questionnaire. After the driving portion of the study was complete, participants were asked to fill out a demographic survey about their age, gender, and driving experience. The driving experience questions gathered information regarding how long they have been licensed, how often they drive (daily, weekly, etc.), approximate yearly mileage, and usual driving environment (rural, urban, suburban, or highway).

Measures

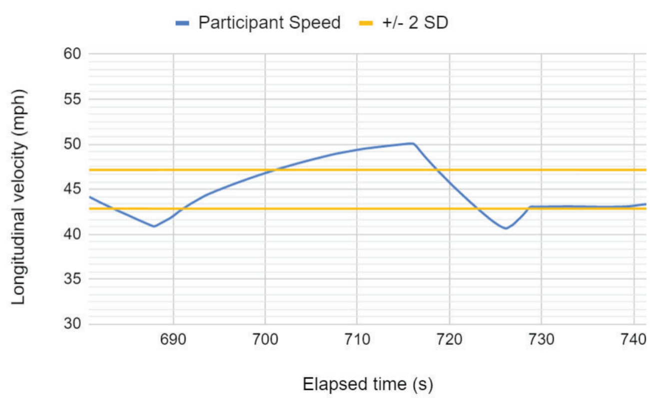
The driving variables measured by the simulator were longitudinal and lateral acceleration, longitudinal and lateral velocity, total longitudinal distance traveled, and lateral lane position. Steering behavior was measured using steering wheel angle and input count. Gas pedal input and elapsed time were also collected. The primary focus was to evaluate elapsed time, longitudinal acceleration/velocity, and the current speed limit. Data points for each variable were collected approximately every .03 second.

RESULTS

To determine if there was an effect of distraction on speed control, the researchers conducted a paired samples t-test between the control and the average of the texting data. The analysis found that there was a significant difference between the control segment (M = 45.3 mph; SD = 2.7 mph) and the distraction segment (M = 44.07 mph; SD = 5.5 mph); $t(18034) = 63.83$, $p < .001$, $d = .29$. Therefore, participants drove slower, which concurs with the previous literature, and exhibited roughly 2 times as much variation while distracted.

Next, the standard deviation of each individual's longitudinal velocity during the control road segment (where they were not engaged in a secondary task) was calculated. Each participant's data was compared to their own control, as opposed to an aggregate mean, to account for individual differences in driving behavior. Each individual SD value was then doubled and used as a cutoff to demarcate the upper and lower bounds of acceptable speed variation. Each time the participants sped up above or slowed down below their individual speed cutoff values was considered a speed violation. An example is included in Figure 3, where the two parallel lines represent the ± 2 SD upper and lower bounds as determined by the participant's control data. The blue line indicates the participant's longitudinal velocity.

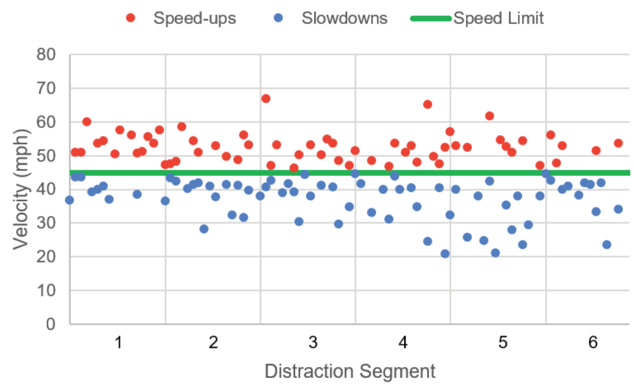
Figure 3: *Example of longitudinal velocity graph.*



Across all participants, there were 96 distraction segments and 16 control segments where data was collected (one distraction segment was thrown out due to a technical error). In the 95 distraction segments, there were 232 speed violations (speed-ups and slowdowns). Speed-ups comprised 39.9% of the violations and slowdowns comprised 60.1%. This relationship is shown in Figure 4, where the red dots indicate speed-ups, the blue dots indicate slowdowns, and the green line indicates the speed limit.

Analysis of the *maximum* and *minimum* velocity variations with respect to the speed limit for each distraction segment revealed that the average maximum speed-up was +7.4 mph, and the average minimum slowdown was -7.7 mph. However, separate analyses of all speed-up and slowdown violations revealed that the average speed-up was +6.1 mph and slowdown was -5.9 mph.

Figure 4: *The distribution of speed violations across each distraction segment.*



Furthermore, each recorded speed-up and slowdown was analyzed to determine how long the participants were considered in violation of appropriate speed variation. The results of this analysis determined that, on average, participants stayed above their cutoff value for 10.9 seconds and below for 13.1 seconds. Based on these results, drivers could travel between 751-816 ft while distracted.

Future analysis of the data aims to explore the minimum and maximum magnitude of the acceleration data, the effect of distraction on lane keeping behavior, and the relationship between these indicators of distraction and various driver characteristics such as age, gender, and driving experience.

DISCUSSION

It is well documented that distraction has negative effects on performance. In relation to driving, this is usually reflected as a decrease in average speed across the driving task (Choudhary & Velaga, 2017; Papantoniou, Papadimitriou, & Yannis, 2017; Ortiz-Peregrina et al., 2020). However, the conclusion that distraction always results in slowing down cannot be made based solely on global measures, such as average velocity. A more granular analysis of velocity over time revealed that there are only slightly more slowdowns than speed-ups (60% versus 40%) and that the magnitude of the slowdown violations in miles per hour is only slightly greater.

Many studies have hypothesized that drivers intentionally slow down in order to increase their reaction time to better respond to driving events (Rakauskas, Gugerty, & Ward, 2004; Haigney, Taylor, & Westerman, 2000). In this case, one would expect speed-ups to be relatively rare under distraction. It is possible that slowdowns are not always a compensatory strategy. This concurs with the diary study conducted by Parnell and colleagues (2020) where participants noted that they did not intentionally alter their driving behavior while performing a secondary task. Alternatively, one might argue that speed-ups represent an overcorrection following slowing down. However, a review of our data reveals that not all speed-ups were preceded by slowdowns.

In many instances, participant speed oscillated above and below the cutoff multiple times within a single distraction segment. Further, there were instances of oscillation even when the magnitude did not exceed the cutoff. The researchers hypothesized that participants may have unintentionally slowed down as a result of an attentional resource shift from the primary driving task to the secondary task then noticed the decline in speed and began to correct. However, they re-engaged with the secondary task and then proceeded to overcorrect. Therefore, the driver's speed began to oscillate as the result of shifting attention between the primary and secondary tasks. Importantly, this interaction between attentional allocation and speed control is only apparent when speed control is analyzed at a more granular level. However, due to the small effect size and small sample size of this study, this claim should be explored further.

In relation to this study, drivers traveled on average almost 800 feet while actively engaged in the secondary task, which is slightly double the length of an American football field. For further reference, the federal guideline for yellow-light intervals at stoplights must fall between 3-6 seconds (McGinty, 2015). This means that participants, on average, were distracted for 2-4 times longer than the duration of a yellow light. This is more than enough time for the driver to miss a traffic light changing from green to red or a pedestrian stepping out in front of their vehicle. Furthermore, the longer a driver is exceeding the speed limit, the more likely they are to be involved in a crash. (Evans, 2004). Continued research in distracted driving is important because crashes that involve distracted drivers killed about 8 people per day in the U.S. in 2018 alone (National Center for Statistics and Analysis, 2020). With this in mind, it is imperative that researchers know exactly how drivers will behave while distracted. The results of this study suggest that there is still more to learn when considering all the driving behaviors that distraction results in.

Study Limitations

A limitation of this study includes the fidelity of the simulator that was used. STISIM 3 is a medium fidelity simulation that does not provide a rich dynamic driving scene and may not provide a driving experience that is exactly the same as real life. Further, participants were more likely to take risks or exaggerate their performance due to the lower risk of driving in a simulator as opposed to driving a vehicle. In addition, the majority of the participants in this study were young adult college students, who are known to be less risk-adverse than their older peers (Choudhary & Velaga, 2019). As a result, our study results may be slightly exaggerated in regard to real-life behavior.

Participants were also required to use a laboratory-provided iPhone XS for their texting device. This is a limitation due to the participants' varying knowledge and experience of texting using an iPhone. Another limitation of the study was the placement of the phone. The phone was held near the dashboard area to the right of each participant. This avoided any confounds regarding the placement of the device in the visual field, but many participants noted that this was not where they regularly held their phone while driving in real life. Further, the texting task differs in a number of respects from natural conversations.

Future Research

For future research regarding distracted driving, it is recommended to explore whether these consequent driving behaviors are intentional adjustments due to perceived risk or unintentional adjustments due to attentional resource shift by adding a physiological measure such as electroencephalogram (EEG) testing. Other driving behavior variables should be considered in addition to this, such as gaze behavior and the attentional ratio between driving and texting. It is also suggested to replicate this experiment in a real-life setting because drivers tend to act differently between simulation and real-world settings. Finally, other input devices, such as radio, GPS, or even the car's own features and designs, should be considered as they also pose a possibility of distracting the driver.

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