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Research article

Texting while driving is a visual problem influenced by phone viewing angle and working distance in young individuals

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A B S T R A C T

Purpose: To investigate the impact of smartphone viewing distance and angle on reaction times.
Design: A prospective, self-controlled, single-center study.
Methods: Participants engaged in a driving simulation facing a large screen with a simulated brake pedal. They were tasked to stop the simulation once recognizing the deceleration of upcoming traffic. Tests were conducted without distraction and with a standardized distraction simulating texting while driving (TWD). Smartphone positions varied at distances of 30 cm and 60 cm, and at angles parallel to and 30° below the road plane. Reaction times were measured from the onset of simulated closure to detection. Stopping distances were extrapolated using data from the National Highway Traffic Safety Administration.
Results: Ninety-four participants were included with a mean age of 24 ± 2.7 years. The control reaction time was 11.5 ± 4.1 s. Reaction times significantly decreased with smartphone placement at a closer distance of 30 cm parallel (17.0 ± 3.3 s) vs 60 cm parallel (15.4 ± 3.8 s), $P < 0.001$. A 30-degree downward placement at 30 cm (18.6 ± 4.0 s) and 60 cm (17.9 ± 3.6 s), further decreased reaction time compared to parallel phone positioning, $P < 0.001$. Extrapolating to stopping distances based on real-world data, smartphone distractions placed at 30 cm 30° below the dashboard had the greatest effect, resulting in a 3 times increase of stopping distance compared to the control, 1201 vs 394 ft respectively, $P < 0.001$.
Conclusion: TWD significantly delays reaction time in young participants. Both the distance and viewing angle of a smartphone significantly influences reaction times during driving simulations. The greatest delays are observed when the smartphone is positioned closer to the user and at a 30-degree angle which we hypothesize is due to vision blur from increased accommodation, loss of stereopsis, and fixation with the peripheral retina.

1. Introduction

Texting while driving is one of many hazardous distractions that can divert a driver's attention from the road. There are three main types of driving distractions: visual, manual, and cognitive [1,2]. Visual distractions involve diverting the driver's gaze away from the road [2]. Manual distractions involve physically engaging activities other than steering the car [2]. Cognitive distractions impair the driver's ability to focus on driving and can include both visual and auditory elements [2]. Regardless of the type, distractions while driving are a deadly problem.

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According to the National Highway Traffic Safety Administration, in 2022, distracted drivers were responsible for 8 % of all fatal crashes, resulting in 3308 deaths [3]. Additionally, distracted driving was a factor in 12 % of all injury-related crashes, affecting 289, 310 people, 11 % of all police-reported crashes, and 621 bystander deaths involving pedestrians or cyclists [3].

However, we do not believe all forms of distractions are equal. We believe there is something unique about cell phone usage. This is a growing concern since global cell phone ownership in 2023 reached an all-time high of 78 % [4]. Furthermore, young drivers appear to be especially at risk for smartphone addiction and related distractions [5,6]. In a study by Yellman et al., 39 % of high school students admitted to texting or emailing while driving [5]. Data from 2018 shows that cell phone owners between the ages of 17–22 touch their phones an average of 1.71 times per minute while driving [5,6]. This is particularly concerning as young people are less likely than adults to respond safely to unexpected events, both in and out of the car, when distracted by a cell phone [7,8].

Our desire to mitigate this growing danger prompts us to question which type of distraction best describes cell phone usage: visual, cognitive, or manual. Understanding the underlying type of distraction will enable us to develop new techniques and technology to potentially solve this issue. A 2023 study by Pelicioni et al. demonstrated a manual distraction component by showing that gait instability during cell phone usage leads to loss of balance [9]. A 2006 study by Wood et al. found that cognitive distraction during visual field tests results in a significant increase in both central and peripheral visual errors, thought to be due to reduced attention to foveal detail [10,11].

While the 2006 study by Wood et al. explores the point where cognition and the physiology of distractions meet, our research takes this further [10]. We hypothesize that visual impairment, rather than inherent distraction, is the main driving force behind accidents involving texting and driving. To test this hypothesis, we designed a self-controlled, prospective study simulating texting and driving utilizing young adults, analyzing the effects of independent variables such as viewing angle and working distance on reaction time.

2. Material and methods

2.1. Participants

A single-center prospective study was conducted at the Louisiana State University School of Medicine. The study was approved by the Institutional Review Board at the Louisiana State University School of Medicine with the approval number: [STUDY00001024]. The study was adhered to the tenets of the Declaration of Helsinki. All participants provided both verbal and written informed consent prior to enrollment in the study. Participants included in the study were men and women over 18 years of age with a best-corrected visual acuity (BCVA) of 20/30 or better, with or without the use of contact lenses or glasses. Visual acuity was measured using the Snellen chart, and the total number of letters read was recorded. Distance measurements for binocular and monocular uncorrected

Fig. 1. Subjects watched a simulated driving video on a large screen with a mock brake pedal.

distance visual acuity (UDVA) were assessed at 6.1 m under 100 % contrast photopic conditions with ambient room lighting.

Exclusion criteria were as follows: participants were excluded if they were monocular, lacked stereopsis (evidenced by an anecdotal history of 3D glasses not working), had a history of glaucoma, had undergone previous ocular surgery, had received pan-retinal photocoagulation treatment, or had a monocular BCVA worse than 20/30.

2.2. Experimental setup

Participants who met the inclusion criteria were then seated directly in front of a large screen and provided with a simulated brake pedal (Fig. 1). They were shown a video from the perspective of a driver following another car, with the distance between the two cars decreasing at an increasing rate. They were instructed to press the mock brake pedal to stop the video as soon as they realized the gap was closing, creating an unsafe distance between their vehicle and the car in front of them (Fig. 2).

2.3. Experimental procedures

A control test for every participant was initially performed without any distraction, with attention focused on the roadway. During this control test, participants were allowed to watch a video simulating driving with the instruction to press a mock brake pedal as soon as they perceived an unsafe distance between their vehicle and the car in front of them.

Next, a uniform level of distraction simulating texting while driving (TWD) was introduced. Participants engaged in a simple math game on an iPhone, which served as a distraction. The iPhone was fixed at two different working distances, 30 cm and 60 cm which represents realistic phone distances in a vehicle. For each distance, participants were tested under two additional conditions: looking straight ahead at an angle parallel to the road plane and looking 30° down from the road plane. A 30-degree downward position was chosen as it is a very comfortable and common position to hold one's phone. Thus, each subject experienced a total of five scenarios.

1. Control (no distraction)
2. iPhone at 30 cm, parallel to the road plane
3. iPhone at 60 cm, parallel to the road plane
4. iPhone at 30 cm, 30° down from the road plane
5. iPhone at 60 cm, 30° down from the road plane

The time point for closure was documented once the subject stopped the video by depressing a mock brake pedal. This approach allowed for the assessment of how different viewing angles and working distances affect reaction times and, consequently, stopping distances.

All experimental procedures were conducted in a controlled environment to ensure consistency and accuracy of the measurements. Participants were given adequate rest between trials to mitigate the effects of fatigue.

2.4. Data processing

Data was recorded in Microsoft Excel for necessary calculations. Reaction times were extrapolated to stopping distances based on real-world data from the National Highway Traffic Safety Administration. The primary endpoints of the study included the assessment of reaction time and stopping distance under both distracted and non-distracted conditions for all participants. These assessments were conducted with distractions presented at various combinations of working distances and viewing angles.

Specifically, the data processing involved the following steps.

1. **Data Entry**: All recorded reaction times for each of the five scenarios (control, and the four distracted conditions) were entered into Microsoft Excel.
2. **Extrapolation to Stopping Distances**: Using established formulas and data from the National Highway Traffic Safety Administration, reaction times were converted into stopping distances. This provided a tangible measure of the impact of different distractions on driving performance.

Fig. 2. Subjects were shown a video from the perspective of a driver following another car. A-B) Depicts a large gap between the open road and upcoming traffic. C) Depicts rapid rate of closure of oncoming traffic, resulting in depression of mock pedal.

3. **Visualization**: Graphs and charts were created to visually represent the data, highlighting differences in reaction times and stopping distances across the various scenarios. This facilitated a clear understanding of the impact of smartphone distractions at different working distances and viewing angles.

2.5. Statistical analysis

SPSS (IBM, Armonk, New York, USA) was used for statistical comparisons of each group. Data groups are presented as mean ± standard deviation where applicable. Independent t-tests were employed for comparing numeric variables, while Chi-square tests for categorical variables were utilized for statistical comparisons. ANOVA was utilized to analysis descriptive statistics between groups. Significance was set at $P < 0.05$.

3. Results

A total of 94 participants were included in the study of which 62 % were female with a mean age of 24 ± 2.7 years of age. All participants were active students in LSU school of medicine. All patients completed the control and testing groups. A total of 46 % (n = 43) of all patients had myopia corrected with contact lenses (n = 29) or glasses (n = 18) compared to 50 % (n = 47) having emmetropia. Among all patients, the most common refractive error was myopia. ANOVA analysis revealed no difference between sex, age, or refractive error between groups.

The reaction time for the control group was 11.5 ± 4.1 s (n = 94) which was significantly faster than all distraction trials, $P < 0.001$. Time to closure with a phone placed parallel to the screen at 30 cm and 60 cm resulted in a decreased reaction time compared to the control, 17.0 ± 3.3 (n = 94) and 15.4 ± 3.8 s (n = 94) respectively, $P < 0.01$ (Fig. 3).

Time to closure with a phone placed 30° down from the screen at a distance of 30 cm and 60 cm resulted in the greatest delay of reaction time from the control at 18.6 ± 4.0 (n = 94) and 17.9 ± 3.6 s (n = 94) respectively, $P < 0.001$ (Fig. 4). Overall, comparison of reaction time among the varying testing groups were not equal. The closer working distance of 30 cm was significantly worse than the distraction group at 60 cm when parallel to the screen (Fig. 4). However, the reaction time with a phone placed 30° down from the screen was significantly worse than the parallel group at 30 cm and 60 cm, $P < 0.01$ and $P < 0.01$ respectively. Nevertheless, time to closure with a phone placed 30° down from the screen at a distance of 30 cm and 60 cm was not significantly different, $P > 0.05$.

The average stopping distance based on the National Highway Traffic Safety Administration at 20, 30, 40, 55, and 65 miles per house was 63, 119, 164, 265, 344, and 387 feet, respectively (Fig. 5A) [12].

Utilizing the reaction time in our data with a Volvo XC90, which has a stopping distance of 180 ft at 70mph on a dry surface, we were able to approximate the stopping distance based on several distraction scenarios. Placing the phone distraction 30 cm from the driver had a significant delay in reaction time, resulting in approximately 2.5 times increase in stopping distance compared to the control, 972 ft vs 395 ft respectively, $P > 0.001$ (Fig. 5B). Shifting the distraction down 30°, 30 cm from the dashboard resulted in approximately 3 times increase in stopping compared to the control, 1201 vs 394 ft respectively, $P < 0.001$ (Fig. 5B).

4. Discussion

Utilizing a real-world video simulation, our data demonstrated that all variations of smartphone distractions had a significant effect on driver reaction time. Our data reinforces numerous studies that texting while driving (TWD) or distractions with smartphones have a negative impact on a driver's overall breaking time, awareness, and control of the vehicle [13–17].

Other studies have demonstrated that mobile phone-related distractions involve the visual pathway, inhibiting participants from adequately using their peripheral mirrors [18]. The visuospatial pathway is further compromised by phone use while driving as more working memory load (e.g., multitasking) increases [19]. Nevertheless, in-vehicle technology, including mobile phone use, involves a multimodality of physiological factors impacting reaction time [20,21]. Understanding these variables and factors is important to

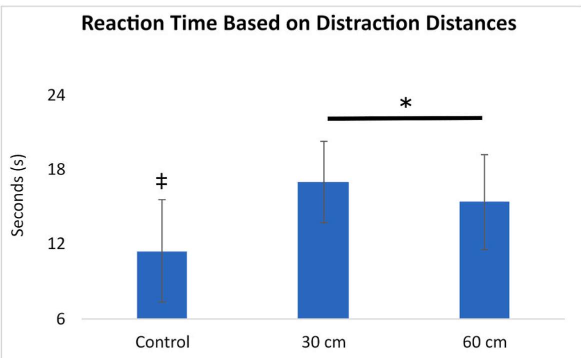

Fig. 3. Time to closure with a phone placed parallel to the screen at 30 cm vs 60 cm resulted in a decreased reaction time, 17.0 ± 3.3 vs 15.4 ± 3.8 s *$P < 0.01$, ‡$P < 0.001$.

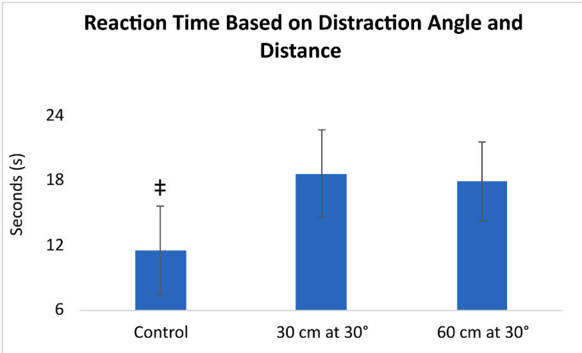

Fig. 4. Time to closure with a phone placed 30° down from the screen at a distance of 30 cm and 60 cm resulted in the greatest delay of reaction time from the control at 18.6 ± 4.0 vs and 17.9 ± 3.6 s ‡P < 0.001.

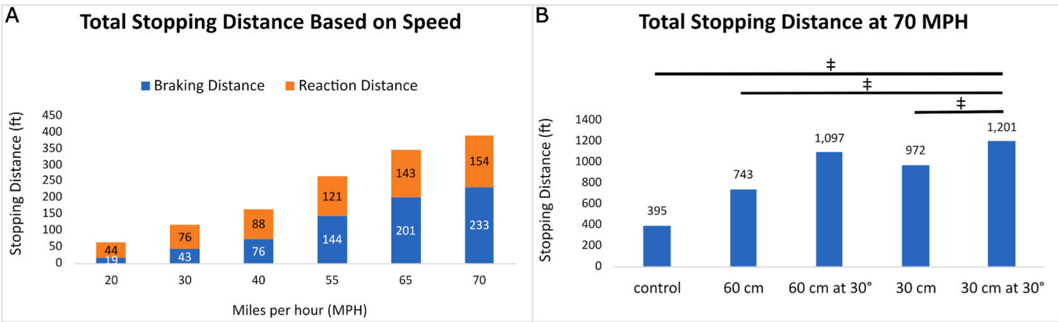

Fig. 5. A) The total stopping distance based on speed by data provided by the National Highway Traffic Safety Administration. B) Utilizing a Volvo XC90 which has a stopping distance of 180 ft at 70mph on a dry surface, the mean stopping distance was three times greater than the control when the distraction was placed at 30 cm, and 30° downward. ‡P < 0.001.

reduced distraction related accidents.

The results from our study are unique as previous experiments did not specifically examine the effect of smartphone positioning. Our data strongly supports that the position and viewing angle of the distraction has a significant overall impact on reaction time. A closer proximity of the distraction from 60 cm to 30 cm had a significant decrease in the participant reaction time, resulting in an increased stopping distance. However, the participant's reaction time was the most decreased when the phone distraction was placed at 30° below the dashboard, 30 cm from the participant. This is clinically significant as the above position represents the most common reading position for phone users. A slight downward and near position of the phone provides better ergonomics and comfort for the individual while also concealing the phone which is illegal to be held for texting in almost all 50 US states.

Extrapolating our data to real-world stopping distances at 70mph on a dry surface, TWD at 30 cm with a 30° downward position resulted in a 3 times increase of stopping distance from 1201 ft (four football fields) compared to a control without any distraction of 395 ft. To further emphasize our results, one must realize that the above stopping distances are under best case scenarios with adequate tires and weather conditions. It is very much possible that stopping distances could be worse in many scenarios.

The other unique finding from our data is that mounted phone distractions, parallel to the dashboard can still have significant effects on reaction time. A phone distraction placed 30 cm and 60 cm parallel to the driver resulted in approximately 2.5 and 1.9 times increase in stopping distance compared to no distraction. Thus the idea that handsfree phone use is safe should be heavily scrutinized, especially when the phone is placed at a closer distance to the driver or is not parallel to the dashboard.

Nevertheless, we hypothesize three possible mechanisms to illustrate how the visual pathway is disrupted while using smartphones, resulting in slowed reaction times. For one, increased near positioning of the distraction increases the level of accommodation. For example, at 60 cm one must accommodate 1.66 diopters, inducing a myopic shift and causing a physiologic blur of distance vision to 20/150. At 30 cm one must accommodate 3.33 diopters, inducing a greater myopic shift and physiologic blur of distance vision to 20/300.

Secondly, binocular fusion for distance is impaired during accommodation. Retinal elements of each eye share a common visual direction known as corresponding elements. These corresponding elements are seen as a single image with both eyes, creating stereopsis. The locus of points in space that create corresponding points in each retina is known as the horopter [22].

Panum's area represents all the surrounding corresponding retinal points which binocular single vision can be maintained. However, only a narrow band around the horopter gives rise to binocular single vision known as Panum's space. Thus, when accommodation puts an image at near, the distance image falls outside of Panum's space, resulting in a diplopic distance image [22].

Diplopic images further reduce the vision quality, causing a physiologic image blur.

Lastly, vision is further decreased for distance with a greater deviation from parallel. As the distraction moved down to 30° from parallel, the distance visual acuity degrades rapidly as fixation involves the peripheral retina. It has been documented that the peripheral retina has worse visual acuity which decreases from one-fourth of the foveal value at 6° to one-sixteenth the foveal value at 30° [23]. Thus vision is further blurred with further extremes of peripheral vision.

Therefore, our data suggests that vision loss due to the angle and distance of handheld phones while driving, are significantly associated with decrease reaction time, potentially increasing the risk for accidents. The reaction time could be improved if devices such as smartphones, could be placed parallel to the road at a maximum working distance. Mirroring smartphone screens onto windshield heads-up displays would create longer working distances and angles parallel to the road, potentially increasing automobile safety.

Nevertheless, we acknowledge several limitations to our study. For one, our patient population was exclusively young, educated drivers currently enrolled in medical school. Our young, educated cohort with a high accommodation level does not represent the wide demographic of current drivers in the USA. Secondly, the driving simulation only focused on reaction time regarding breaking in front of oncoming traffic. It is very likely that we oversimplified the reaction time involved during the complexities of driving.

Further testing on a wider age group as well as patients with ophthalmic conditions such as glaucoma, macular degeneration, and cataracts needs to be performed to understand how smartphone distractions affect alternative groups. Further research should also involve utilizing smartphone distraction with newer generations of dashboard heads up displays (HUD) to determine if delays in reaction times can be mitigated.

5. Conclusions

Distracted drivers are associated with a significant number of fatal crashes involving other vehicles or non-vehicle bystanders. Our data, simulating TWD, reinforces that reaction time significantly decreases in all participants when a smartphone distraction is present. The impact of the distraction was associated with the position of the distraction. A closer proximity of the distraction with a 30° deviation from parallel, resulted in the worst reaction time which we hypothesize is due to vision blur from increased accommodation, loss of stereopsis, and decreased acuity associated with fixation of the peripheral retina.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Stephen A. LoBue: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. **Curtis R. Martin:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Thomas M. Catapano:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Kelli M. Coleman:** Writing – original draft, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Sarah Martin:** Writing – original draft, Investigation, Formal analysis, Data curation. **Sofia Plascencia:** Writing – original draft, Resources, Investigation, Data curation. **Christopher L. Shelby:** Writing – original draft, Investigation, Data curation, Conceptualization. **Wyche T. Coleman:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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