Texting While Driving: Is Speech-Based Texting Less Risky than Handheld Texting?

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ABSTRACT
Research indicates that using a cell phone to talk or text while maneuvering a vehicle impairs driving performance. However, few published studies directly compare the distracting effects of texting using a hands-free (i.e., speech-based interface) versus handheld cell phone, which is an important issue for legislation, automotive interface design and driving safety training. This study compared the effect of speech-based versus handheld texting on simulated driving performance by asking participants to perform a car following task while controlling the duration of a secondary texting task. Results showed that both speech-based and handheld texting impaired driving performance relative to the drive-only condition by causing more variation in speed and lane position. Handheld texting also increased the brake response time and increased variation in headway distance. Texting using a speech-based cell phone was less detrimental to driving performance than handheld texting. Nevertheless, the speech-based texting task still significantly impaired driving compared to the drive-only condition. These results suggest that speech-based interaction disrupts driving, but reduces the levels of performance interference compared to handheld devices. In addition, the difference in the distraction effect caused by speech-based and handheld texting is not simply due to the difference in task duration.

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1. INTRODUCTION
Distracted driving is a growing public safety hazard. Drivers engage in many distracting behaviors while they drive, including talking, dialing, texting, and E-mailing [28]. Naturalistic studies of cell phone use suggest that driver distraction increases crash risk by 2.8 to 5 times [16, 27, 37, 38], risk-levels comparable to drunk driving [27]. A survey by the American Automobile Association (AAA) reported that 14.1% of all drivers and 48.5% of young drivers age 18 to 24 admitted that they text while driving [1]. The increasing usage of cell phones has been accompanied by an accelerating increase in the number of traffic accidents [2, 31, 42, 43]. The high risk of texting while driving has attracted the attention of legislators, automakers, and safety researchers.

A common misperception underlying legislative efforts is that the task of holding a phone represents the primary source of interference with driving, despite evidence showing that hands-free cell phone use still impairs driving performance [23, 31]. This assumption has influenced automotive interface design and legislation in the United States. Thirty-nine states have passed legislation banning texting while driving and ten states have banned handheld cell phone use for all drivers. However, interestingly, all states still allow hands-free cell phone use while driving [24]. In addition, automotive manufacturers are designing speech-based systems to replace handheld interaction [19]. A critical question underlying these legislative and system design decisions is “whether texting using a speech-based phone is less risky than using a handheld phone?”
According to one theoretical account termed the manual and visual structural interference hypothesis, the effect of cell phone use on driving performance derives from the need to hold the phone and press the keys, and the visual distraction caused by the need to move the eyes and attention between the cell phone and the road scene [39]. Driving is primarily a manual-visual-spatial task, requiring frequent steering control [29]. Handheld cell phone use requires the same manual and visual resources as driving, creating a structural interference [39, 40]. Manual manipulation of equipment, such as dialing and answering the phone, tuning the radio and DVD player, impacts driving performance negatively [4, 5, 11, 12, 34].

In agreement with the structural interference hypothesis, performance advantages of speech-based cell phone use have been reported previously [22, 25, 32]. Owens and colleagues reported that speech-based interaction reduced the number of glances and total glance durations to the texting task, and reduced subjective mental demand relative to handheld dialing and music track selection tasks [25]. The frequency and duration of “eyes off the road” glances increases when talking or texting [14, 35]. Both are positively correlated with higher collision rates. Drivers using a speech-based personal digital assistant (PDA) are faster in responding to an emergency than when they are required to interact manually with the PDA. Reactions times in both conditions were slower than the drive-only condition [22].

An alternative perspective is that speech-based texting provides little advantage over handheld texting, because the primary source of interference is cognitive. Cognitive distraction is associated with the central executive component of working memory [18, 20]. We refer to this hypothesis as the cognitive interference hypothesis hereafter. Interference between driving and other tasks (i.e., talking or texting) is a direct result of the serial processing nature of the central executive. The central executive can only execute one information-processing task at a time, such as language production or steering control but not both tasks concurrently [18, 31]. The cognitive interference hypothesis predicts similar levels of task interference for both handheld and hands-free cell phone.

The cognitive interference hypothesis is supported by meta-analytic and empirical studies of cell phone conversation while driving. These findings reveal that a hands-free cell phone conversation provides little performance benefit over handheld conversation [8, 13, 20, 23, 31]. Levy and colleagues reported similar brake response times for manual and verbal responses to a choice task [20]. Similarly, it’s been shown that performance in a simulated driving task was not impaired by listening to radio broadcasts, listening to a book on a tape, or by a continuous shadowing task using a handheld cell phone [31]. In contrast, a word generation task hindered driving performance [31]. These data imply that cognitive interference, rather than structural interference, is the major cause of the performance decrement caused by distracted driving. Cell phone conversations disrupt driving performance by diverting attention to cognitive tasks [31].

Most of the abovementioned studies used non-texting tasks, such as cell phone conversations. Although texting and conversations using cell phones have some elements in common, it is important to acknowledge their differences. For instance, a manual texting task requires the driver to look at the phone and press the correct buttons frequently, while a handheld cell phone conversation imposes less visual and manual distraction. Drivers who are manually texting can choose when to text, whereas a driver engaging in a cell phone conversation may feel obligated to maintain the conversation [10, 15]. The task interference found in hands-free versus handheld cell phone conversation may not apply to texting while driving directly.

Despite its importance, few studies have compared the distracting effect of speech-based and handheld texting directly (for limited number of examples, see [10, 14, 33]). The comparison of speech-based and handheld texting requires control of an important confounding variable, the duration of the secondary texting task. The overall level of task interference represents the interactive effects of the duration of the secondary task and the magnitude of interference a task has on driving performance. This study addresses the confounding variable of task duration of speech-based and handheld texting by controlling the duration of the texting tasks to be exactly the same using a smartphone texting application [6, 35]. This study uses a car following task motivated by: 1) research showing that mobile users have a higher risk of rear-end collisions [41] and that cell phone use has a larger effect on driver reaction time than tracking performance [13].

2. METHOD

2.1 Participants

Thirty-five college-age participants (10 men and 25 women, $M = 21.70$ years of age, $SD = 3.60$ years of age) from Wichita State University volunteered to participate in this driving experiment. All participants were screened prior to participation to ensure normal or corrected-to-normal vision. All participants were active drivers with at least 2 years of driving experience ($M = 6.34$ years; $SD = 3.57$ years) and were required to own a touch screen smartphone to ensure familiarity with the cell phone used in the experiment. On average, participants reported sending 98.44 text messages per day ($SD = 50.0$).

2.2 Apparatus and Stimuli

2.2.1 Driving simulator

Driving behavior was assessed in a driving simulator, consisting of a driver’s seat, a Logitech Driving Force GT steering wheel, and pedals, as shown in Figure 1. The steering wheel’s spring effect, damper effect, and centering spring strength were at 50% and had 900 degrees of rotation. Customized simulation software using the framework of The Open Racing Car Simulator (TORCS; torcs.sourceforge.net, version 1.3.3) was used for the driving simulation. The simulated driving task was displayed on a 60” Sharp AQUOS 3D HD LCD television, with a resolution of 1080x1920 and a refresh rate of 60 Hz. The visual angle of the viewable driving scene was 15.30 degrees by 10.22 degrees. The simulator shows road and traffic information from inside the car and through a rear-view mirror. The simulation program has been used to examine the lane-keeping performances of drivers with different levels of driving experience [7].

A 4.3” HTC ThunderBolt touch-screen smartphone running the Android 2.3.4 operating system was used for the texting task. The buttons on the keyboard of the smartphone were arranged in a QWERTY layout.

A RCA RP5120 audio recorder was used to record the audio response for the speech-based texting task.
2.3 Experiment Tasks

2.3.1 Car following task
A car following task was used to measure driving performance under distraction [17, 30]. Participants were instructed to follow a lead vehicle while maintaining a safe distance, as shown in Figure 2. The lead vehicle drove at a target velocity of 30 miles per hour, and braked at random time intervals, which followed a uniform distribution with the range of 30 to 60 seconds. During a brake event, the lead vehicle decelerated at the rate of 3m/s² for 5 seconds and then returned to the target velocity of 30 mph afterwards. If the participants drove too slowly with a headway distance greater than 100 m, the lead vehicle would gradually slow down at the deceleration rate of 0.5 m/s² until the headway distance was smaller than 80 m. Participants were asked to observe all traffic laws. During the driving scenario, headway distance, lane position, steering wheel position, and speed were recorded.

The simulated driving scenario consisted of an 8000 m long two-lane highway (with straight and curved portions). Traffic included recorded distance, lane position, steering wheel position, and speed were included. The participant’s vehicle and a lead vehicle.

2.3.2 Texting task
A texting task was used to assess the effects of two separate response modalities (verbal vs. manual) on driving performance. Participants were instructed to repeat a text message, either verbally or manually on the cellular phone. The text message consisted of a 10-digit telephone number presented to participants via a texting application installed in the HTC Android smartphone. Drivers enter letters and symbols in addition to numbers in real-world texting. The texting task using 10-digit numbers was intended to simulate the cognitive process and manual entry in a cell-phone dialing or texting task while make it easy to measure secondary texting performance.

An incoming texting message sound was played at a random time interval, which followed a uniform distribution in the range of 40 to 60 seconds. Upon hearing the incoming texting message sound, participants started the texting application, which displayed a 10-digit telephone number. Participants replied by repeating the same telephone number either manually or verbally. The text message would display for 10 seconds, after which the program would automatically close, and participants were instructed to stop texting. The ending of the texting task was cued by a beep sound. If participants responded to an entire message before the message application closed, another random 10-digit number was presented. This ensured that the texting task lasted for exactly the same duration. A digital voice recorder was used to record participants’ verbal responses to the text messages.

2.4 Procedure
Once the participants arrived at the lab, the nature and purpose of the experiment was explained and a written consent to participate was obtained. Next, they were asked to complete a questionnaire regarding driving experience and cellular phone use, and their Snellen visual acuity was measured to ensure they had 20/20 acuity.

There were five counterbalanced conditions (balanced Latin square). These included a driving-only condition, two dual task conditions in which participants drove while texting manually (drive + manual) or verbally (drive + verbal), and two texting only conditions in which participants only did the manual or speech-based texting task.

The session began with a short practice session in order for the participants to get accustomed to the control of the simulator and the cell phone. Participants practiced each of the conditions for two minutes, for a total of 10-minutes of practice. After the practice, participants began the experimental part of the session. Each condition lasted about 12 minutes. The entire session lasted about 90 minutes and participants were informed that they could withdraw from participation at any time.

2.5 Data Analysis
Driving performance was assessed using the car following task and lane keeping behavior. The measurements for car following included brake response time, braking response rate, mean and standard deviation of headway distance, mean and standard deviation of speed. Brake response time was measured from the onset of the lead vehicle braking until the initiation of a braking response by participant vehicle. A brake response was operationally defined as a minimal depression of 1% of the brake pedal [29]. A no braking response was defined as a failure to brake within 5 seconds after the lead vehicle braked. The headway distance was measured from the rear of the lead vehicle to the bumper of the subject vehicle.

The measures of lane keeping performance included the mean and standard deviation of lane position. The zero reference point of lane position was the center of the right lane. Large value of the standard deviation of lane position indicates poorer lane-keeping performance with higher risks of lane departure and collision with
vehicles in the side lanes. A positive value of lane position indicates a position left of the center of the right lane.

All dependent variables were submitted to one-way analyses of variance with task conditions as the only within-subject factor. IBM SPSS v18.0 was used in the statistical analysis. All the assumptions for an ANOVA were met in the reported data.

3. RESULTS

3.1 Car Following

Brake response time differed significantly across task conditions, F (2, 68) = 4.14, p = .02, \( \eta^2_p = .11 \). As shown in Figure 3, the simple main effect analysis shows that the brake response time under drive-only condition (\( M = 1.49 \) sec, \( SD = 0.56 \) sec) was significantly shorter than that under the drive + manual condition (\( M = 1.73 \) sec, \( SD = 0.48 \) sec), \( t(34) = 2.52, p = .02 \). The brake response time did not differ between the drive-only and drive + verbal condition (\( M = 1.63 \) sec, \( SD = 0.47 \) sec), and the drive + verbal and drive + manual condition, \( t(34) = 1.50, p = .14 \) and \( t(34) = 1.69, p = .10 \) respectively.

Analysis of braking response rate did not produce any significant results, F (2, 68) = 0.92, p = .40, \( \eta^2_p = .03 \).

The standard deviation of headway distance also produced a significant main effect of task conditions, \( F(2, 68) = 6.90, p = .002, \eta^2_p = .17 \). As shown in Figure 4, the standard deviation of headway distance in the drive-only condition (\( M = 15.36 \) m, \( SD = 7.45 \) m) was significantly larger than that in the drive–only condition (\( M = 11.36 \) m, \( SD = 6.49 \) m) and the drive + verbal condition (\( M = 12.72 \) m, \( SD = 5.43 \) m), \( t(34) = 3.34, p = .002 \) and \( t(34) = 2.69, p = .01 \) respectively. However, the standard deviation of headway distance did not differ for the drive-only and drive + verbal condition, \( t(34) = 1.25, p = .22 \).

The mean headway distance was significant across task conditions, F (2, 68) = 3.17, p = .048, \( \eta^2_p = .09 \). As shown in Figure 5, the mean headway distance in drive + manual condition (\( M = 26.45 \) m, \( SD = 11.00 \) m) was significantly larger than that in the drive–only condition (\( M = 21.30 \) m, \( SD = 11.18 \) m), \( t(34) = 2.86, p = .01 \). The mean headway distance did not differ between the drive-only and drive + verbal conditions (\( M = 29.26 \) m, \( SD = 11.95 \) m), \( t(34) = 1.25, p = .22 \), nor did it for the drive + verbal and drive + manual conditions, \( t(34) = 1.13, p = .27 \).

The standard deviation of speed produced a significant main effect of task conditions, F (2, 68) = 3.04, p = .05, \( \eta^2_p = .08 \). As shown in Figure 6, the standard deviation of speed in the drive-only condition (\( M = 6.46 \) mph, \( SD = 0.84 \) mph) was significantly smaller than in the drive + verbal condition (\( M = 6.75 \) mph, \( SD = 0.97 \) mph) and marginally smaller than in the drive + manual condition (\( M = 6.77 \) mph, \( SD = 1.15 \) mph), \( t(34) = 2.09, p = .04 \) and \( t(34) = 1.99, p = .055 \) respectively. The standard deviation of speed did not differ between the drive + verbal and drive + manual conditions, \( t(34) = 0.15, p = .89 \).

Mean speed did not differ across task conditions, F (2, 68) = 0.75, p = .48, \( \eta^2_p = .02 \). The data suggest that distracted drivers did not compensate for the increasing risks of driving while texting by reducing their driving speed.

A series of Mann-Whitney U tests revealed no significant gender differences for standard deviation of lane position and mean lane position in the drive-only, drive + verbal, and drive + manual conditions.
3.2 Lane Keeping
The standard deviation of lane position was significantly different across task conditions, \( F(2, 68) = 31.95, p < .001, \eta^2_p = .48 \). As shown in Figure 7, the standard deviation of lane position in the drive-only condition (\( M = 0.37 \text{ m}, SD = 0.12 \text{ m} \)) was significantly smaller than that in the drive + verbal condition (\( M = 0.41 \text{ m}, SD = 0.10 \text{ m} \)) and drive + manual condition (\( M = 0.51 \text{ m}, SD = 0.15 \text{ m} \)), \( t(34) = 2.84, p = .01 \) and \( t(34) = 6.22, p < .001 \) respectively. The standard deviation of lane position in the drive + manual condition was also significantly larger than that in the drive + verbal condition, \( t(34) = 6.14, p < .001 \).

The mean lane position also differed significantly across task conditions, \( F(2, 68) = 5.53, p = .01, \eta^2_p = 0.14 \). As shown in Figure 8, the mean lane position in the drive-only condition (\( M = 0.23 \text{ m}, SD = 0.20 \text{ m} \)) was significantly smaller than that in the drive + verbal condition (\( M = 0.28 \text{ m}, SD = 0.21 \text{ m} \)), and drive + manual condition (\( M = 0.30 \text{ m}, SD = 0.19 \text{ m} \)), \( t(34) = 2.16, p = .04 \) and \( t(34) = 2.79, p = .01 \) respectively. The mean lane position in the drive + verbal condition was not significantly different from the drive + manual condition, \( t(34) = 1.41, p = .17 \).

4. DISCUSSION
The results of this study indicate that both handheld and speech-based texting significantly affect driving performance. Handheld texting increased brake response time, increased variation in headway distance and lane position. Drivers who texted using a handheld smartphone had greater following distances and drove further towards the left lane boundary. These behaviors may represent a compensatory strategy chosen to offset the perceived risk of the secondary handheld texting task [15]. Driving performance in the speech-based texting condition was better than in the handheld texting condition. Nevertheless, speech-based texting still affected driving performance, as demonstrated by a larger standard deviation of speed and lane position in the drive + verbal condition compared to the drive-only condition. No evidence of compensatory behaviors were observed in the drive + verbal condition.

Our results are consistent with previous studies reporting longer brake response time [22], impaired lane-keeping [9, 10] and longer headway distance [10, 14] when drivers engage in a texting task. This study provides a fairer comparison of handheld versus speech-based texting by equating the duration of the texting task.

Handheld texting had a greater detrimental effect on the drivers’ performance than speech-based texting, even after equating the task duration. Several driving studies have reported that manual and visual distractions hinder performance, a finding which supports the structural interference hypothesis [26, 32]. This offers evidence that implementing speech-based technologies can reduce manual and visual interference compared to handheld texting.

Despite its advantage, speech-based texting still impairs driving performance. This is consistent with the notion that limitations associated with later stages of cognitive processing (e.g., central executive) may account for the distracting effects of secondary tasks. Although speech-based texting reduces or removes structural interference, the performance effect on driving still persists, because of the cognitive load associated with the texting task.

Our results offer some evidence of drivers adopting a compensatory strategy to offset the increasing driving risks.
associated with a secondary task [15]. This strategy includes increasing headway distance, reducing speed, and anticipating the behaviors of lead vehicles and pedestrians [15]. This behavior has been reported in several other studies [10, 14, 33]. However, distracted drivers do not always adopt compensatory strategies in response to increasing driving risks. For example, Alm and Nilsson [3] reported that drivers engaging in a mobile telephone task did not compensate for slower reaction times by increasing their headway distances. Similarly, we found that drivers in the drive + verbal condition did not increase their headway distance or reduce their speed.

A practical application of these findings for automakers and aftermarket in-vehicle system designers would be the implementation of speech-based systems to reduce the manual and visual structural interference, thereby improving driving safety. However, it is important to keep in mind that speech-based texting while driving remains hazardous. Despite its performance advantage over handheld texting, hands-free texting is not a panacea that eliminates all the interference on driving performance. The best recommendation is that drivers avoid all distractions, including both speech-based and handheld texting, and focus on driving.

This experiment assumed speech recognition was perfect in the speech-based texting condition, which is not representative of existing speech recognition technologies. The accuracy of speech recognition may be an important factor in determining the risks of speech-based texting to driving performance. In this experiment, subjects were just asked to repeat the digits shown in the speech-based texting to driving performance. In this experiment, the reported risks of speech-based and manual texting to driving may be underestimated.

Future studies should explore how the accuracy of speech recognition technology changes driving performance and whether the compensatory behaviors are deliberate strategies or products of distraction resulting in reduced muscle tension and pressure on the gas pedal. Researchers can also investigate legislative, training, social and technological approaches to discourage risky driving behaviors, such as cell phone conversation and texting.

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6. REFERENCES


