Effect of cellular telephone conversations and other potential interference on reaction time in a braking response

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Abstract

This experiment studied the effect of phone conversations and other potential interference on reaction time (RT) in a braking response. Using a laboratory station which simulated the foot activity in driving, 22 research participants were requested to release the accelerator pedal and depress the brake pedal as quickly as possible following the activation of a red brake lamp. Mean reaction time was determined for five conditions: (a) control, (b) listening to a radio, (c) conversing with a passenger, (d) conversing using a hand-held phone, and (e) conversing using a hands-free phone. Results indicated that conversation, whether conducted in-person or via a cellular phone caused RT to slow, whereas listening to music on the radio did not.

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1. Introduction

The widespread use of cellular phones by automobile drivers has recently generated safety concerns (Haigney, 1997; Haigney and Westerman, 2001). Particularly influential was a study by Redelmeier and Tibshirani (1997) which found that the use of cellular telephones in automobiles was associated with a quadrupling of collision risk during the brief period of the call. This and other research has suggested that the use of phones while driving can impair aspects of driving performance, possibly increasing accident risk (Alm and Nilsson, 1995; Brookhuis et al., 1991; Brown et al., 1969; McKnight and McKnight, 1993). A debate has ensued concerning the need for legislation restricting the extent to which drivers are permitted to operate a phone in a moving automobile. In the US, efforts to enact laws limiting or prohibiting the use of phones by drivers have increased. One state (New York) and several local municipalities have already restricted the use of phones by drivers.

Most traffic regulations in the US and around the world that apply to cellular phones and driving have focused on the potentially undesirable effects of manipulating a hand-held phone while driving (Lamble et al., 1999), typically by banning the use of hand-held phones, but not hands-free models. Evidently there is a belief that a majority of phone-related accidents occur when a driver is reaching for, dialing, or holding a phone, (it should be noted that unless a hands-free cellular phone uses voice recognition, it too requires manual dialing). Undeniably, manual phone dialing can have a negative effect on driving precision and potentially safety, largely because of the visual demands of manual dialing (Green et al., 1993; Serafin et al., 1993). Relatively long-duration gaze fixations are required to read a phone number and to dial it using a keypad (Reed and Green, 1999). Dialing a phone while driving has been rated as more difficult than most typical driving tasks (Kames, 1978), and data from Japan showed that the majority of cellular phone-related crashes occurred during dialing or receiving calls (National Highway Transportation Safety Administration, 1997).

In contrast, limited US crash data have suggested that a majority of cellular phone-related crashes occur during conversations (National Highway Transportation Safety Administration, 1997). Moreover, Redelmeier and Tibshirani (1997) found no safety advantage to using hands-free compared to hand-held phones, suggesting that accidents result from a driver’s limited attention rather than limited dexterity (like that caused by dialing the phone, holding it, putting it back, etc.). Maclure and Mittleman (1997) contend, however, that Redelmeier and Tibshirani’s study was too small and had too little statistical power to determine whether hands-free phones are safer than hand-held models. Nevertheless, Lamble et al. (1999) provided some support for...
Redelmeier and Tibshirani’s assertion when they found that drivers’ ability to detect deceleration in a leading car was impaired equally by a ‘non-visual cognitive task’ (meant to simulate a phone conversation) and a keypad dialing task. Apparently, both visual and non-visual cognitive resources are important, such that looking at, manipulating, and using a phone while driving can each affect accident risk (Lamble et al., 1999).

There remain important unanswered questions regarding the effect of phone use on driving performance. It is unclear precisely how the use of phones could contribute to vehicle accidents. The assumption, of course, is that phone use generates interference—but what kind of interference? Tasks can interfere with one another for a variety of reasons, only some of which would be interpretable as interference due to limitations in some central capacity (attention), that is, capacity interference. In contrast, structural interference results when physical structures are the source of the performance decrement (Schmidt and Lee, 1999). A hand can only be one place at a time, and the eyes can be focused only on one signal source at a time. For example, reading a road map while driving could interfere physically with the detection of a road hazard and consequently, delay initiation of an avoidance maneuver. It is possible, even probable, that road map while driving could interfere physically with the detection of a road hazard and consequently, delay initiation of an avoidance maneuver. It is possible, even probable, that

The critical question is this: how does interference potentially generated by cellular phone use compare to that potentially generated by a variety of common secondary tasks? It is sometimes argued that cellular phones are no worse than other potential distractions drivers encounter routinely, such as conversing with a passenger, eating, drinking, or listing to the radio (Fix, 2001). If this is true, banning the use of phones by drivers while ignoring the risk created by other potential distracters would appear to unreasonably single-out phones for prohibition, especially given the potential benefit of having a phone when traveling by automobile, such as the ability to summon assistance in an emergency. Because little is known about whether phone use is more or less distracting than other secondary tasks, the primary aim of this experiment was to determine the effect of cellular phone conversations and other potential interference on reaction time (RT) in a braking response. RT in a car-following situations is a valid performance parameter, and potentially suitable as part of a driving performance test (Brookhuis et al., 1994).

2. Methods

2.1. Participants

Twenty-two (N = 22) young adults, 11 women and 11 men, between the ages of 18 and 27 years (mean = 21, S.D. = 2.1) participated in the experiment. All participants were licensed drivers, and were recruited by word of mouth from among students at Miami University. Seventeen of the 22 participants had used a cellular phone while driving at least once prior to participating in the study.

2.2. Apparatus

The apparatus used for the experiment consisted of a laboratory station designed to simulate the foot activity in driving a vehicle with automatic transmission. Included were accelerator and brake pedals, positioned similar to those in an automobile. The chair in which participants sat was situated so that they assumed a posture similar to that in driving. A red lamp, 5 cm in diameter, was positioned 2.0 m from the participant’s eyes so as to subtend a visual angle of 1.4°. In actual driving, a brake lamp 30 cm in diameter and a distance of 12 m from an observer would subtend exactly the same visual angle. The apparatus was equipped to measure RT in braking.

2.3. Procedures

Participants sat at the apparatus (hands resting on their laps), placed their right foot on and depressed the accelerator pedal and awaited activation of the red brake lamp positioned in front of them. Participants were instructed to release the accelerator as quickly as possible and depress the brake pedal as quickly as possible following activation of the red lamp. RT, the time between activation of the red lamp and the initial movement of the foot from the accelerator pedal, was recorded in milliseconds. Each trial included a variable and random 10-20 s delay between initiation of the trial and activation of the red lamp to which the braking response was made. Participants were provided a minimum of seven practice trials to become familiar with the task. Following a short break participants were again instructed to perform the braking task as quickly as possible in response to the red lamp’s activation, while at the same time performing a secondary task including using a cellular phone.

Participants performed five trials under each of five conditions (A–E), for a total of 25 trials. The five trials for each condition were presented in a blocked fashion, and the order in which conditions were presented was counter-balanced across participants. In condition A (control), participants did not view, handle, or use the cellular phone in any way. In condition B, participants listened to music played on a radio. For each of the five trials, a different contemporary song was played at a moderate volume. Condition C required participants to engage in a conversation with a research assistant who played the role of a vehicle passenger. The passenger was positioned as if he were seated in the right-rear passenger seat. The participant was requested keep their gaze focused on the red lamp during the conversation, rather than turning to look at the passenger. The conversation involved the passenger asking the participant straightforward questions in such a way as to simulate a relaxed conversation one might have with a new acquaintance. The questions sought basic information about the participant, including the nature
Note: a repeated measures ANOVA was significant, $F(4, 18) = 38.51, P < 0.0001$, and accordingly, pairwise comparisons were performed using Tukey simultaneous tests. The comparisons revealed significant differences between conditions A and C ($t = 9.28, P < 0.0001$), and E ($t = 9.43, P < 0.0001$). Significant differences were also found between conditions B and C ($t = −5.77, P < 0.0001$), D ($t = −7.21, P < 0.0001$), and E ($t = −7.36, P < 0.0001$). There was no significant difference between conditions A and B ($t = 2.07, P > 0.05$), nor between conditions C and D ($t = 1.44, P > 0.05$), C and E ($t = 1.59, P > 0.05$), and D and E ($t = 0.15, P > 0.05$). In other words, conversation caused RT to slow whether it was conducted in-person or via a hand-held or hands-free cellular phone, whereas listening to a radio did not. Finally, there was no significant difference between the mean RT performance of women (mean = 437 ms, S.D. = 43), and men (mean = 436 ms, S.D. = 26), and this was true for all conditions.

4. Discussion

4.1. Cellular phone use and reaction time

This experiment sought to determine the effect of cellular telephone conversations and other potential interference on RT in a braking response. The results supported the first hypothesis—that phone use would cause poorer RT performance in the braking task. The mean difference between condition A (control) and the average of conditions D and E (phone) was +72.5 ms. That is, phone use caused RT to slow by 19%. This finding is consistent with the effect of phone use on RT previously reported by Alm and Nilsson (1995), Brookhuis et al. (1994), Brown et al. (1969), and in particular Irwin et al. (2000) who found a 24% slowing in braking RT using a similar task. Because of the simulated nature of the experimental task, the results of the present study are only indirectly related to driving. Nonetheless, the potential relevance of increased RT in braking responses for traffic safety is easily inferred. Rear end collisions account for approximately 40% of all traffic accidents (McKnight et al., 1989). Brake lamps usually provide the first alarm signal for a driver at risk for a rear end collision because they activate before the gap between two vehicles begins to close. Interference that slows RT, such as that potentially generated by cellular phone use, could affect the frequency and severity of rear end collisions by increasing response time (of which RT is a component).
4.2. Conversation with a passenger and reaction time

The results supported the hypothesis that RT would be significantly worse under condition C (conversation with passenger) than under the control condition (A). Indeed, condition C produced an effect on RT comparable to the average of conditions D and E (phone), slowing it by 16%. Apparently, there was little difference between the interference generated by the conversation with a passenger and that produced by the conversation conducted using the cellular phone. It has been argued that cellular phones are no worse than other distractions drivers face routinely, such as conversing with a passenger, eating, drinking, smoking, or listing to the radio (Fix, 2001). Within the constraints imposed by this experiment, this line of reasoning appears to be accurate, at least regarding conversation with a passenger.

In real world driving, however, there are often important differences between conversing with a passenger and conversing with someone via a cellular phone that were not accounted for in the experiment. In real world driving, conversations with passengers are typically self-paced, in that they may be suspended or adapted at any moment when the demands of driving require increased attention. In contrast, phone conversations are typically paced, in that there is a greater expectation of continuous conversation, regardless of the driving demands. Unlike a passenger, a person on the other end of a phone conversation cannot see when roadway situations require the driver’s complete attention (McKnight and McKnight, 1993). Moreover, the degree to which a driver is distracted by conversation with a passenger may be to some extent compensated for by the added capacity for roadway observation offered by the passenger. Consequently, paced (e.g. phone) conversations would be expected to result in a higher cognitive demand experienced by the driver (Haigney and Westerman, 2001).

When conversation occurred in the present experiment, it was always paced, even in condition C (with the passenger). The passenger followed scripted questions which resulted in nearly continuous conversation. Neither the driver nor passenger could anticipate when the red lamp would activate. Consequently, there was never cause for the driver or passenger to suspend or adapt the conversation in anticipation of lamp activation and the subsequent braking response. Although in real-world driving, paced conversations with passengers are probably not as common as self-paced, real-world driving unquestionably involves rapid braking in response to unanticipated events. Therefore, the conversations which occurred in condition C were realistic within the context of situations where the sudden need for a driver’s increased attention is not, or cannot be anticipated.

In short, the results of the present experiment indicate that RT in braking can be slowed by paced conversations (passenger or phone), and common sense argues that this impairment has potential to, for example, increase the frequency and severity of rear end collisions by increasing response time. This can be illustrated by the following example. Suppose one is driving on a highway at a speed of 65 mph (29.1 m/s) and the driver of a car just ahead suddenly applies the brakes. If a roughly similar effect occurred due to engaging in a paced conversation (passenger or phone), then the driver of the trailing vehicle would use an additional 2.01 m (6.6 ft) to come to a stop. Obviously it will be important to study the effect of self-paced conversation on drivers’ RT, although it will be difficult to do so using low-cost simulation.

4.3. Hand-held versus hands-free phones

Support was also found for the hypothesis that the hands-free phone would not provide an advantage over the hand-held model. As predicted, conditions D and E produced nearly identical performance decrements, and therefore, appear to have been equally attention demanding. The increased processing time observed in both phone conditions can be attributed to capacity interference rather than structural interference. At no time did both tasks, braking or conversing, simultaneously require visual fixation on more than one signal source (simulated brake light), or require use of the hands for more than one function (holding the cell phone). In other words, conditions D and E imposed no structural interference, yet still caused significant and equivalent declines in braking performance. This is not to suggest that hands-free phones could not be advantageous in certain situations, because they probably could. Nonetheless, it is clear that a hands-free phone cannot totally alleviate the problem of performance impairment when using a cellular phone.

Most traffic regulations that apply to cellular phones and driving have focused on the potential undesirable effect of manipulating a hand-held phone while driving (Lamble et al., 1999), typically by banning the use of hand-held phones, but not hands-free models. The focus on restricting the use of hand-held phones exclusively is based on the assumption that the only way in which phone use may be distracting to drivers is by introducing structural interference. Results of the present experiment suggest that this assumption is mistaken. Capacity interference produced by the hands-free phone conversation was sufficient to significantly delay braking RT.

4.4. Radio listening and reaction time

Finally, results of the experiment supported the hypothesis that listening to music played on a radio would generate minimal interference, and thus not effect braking performance. The prediction was based on the perception that being in the presence of an audible signal such as music does not necessitate the allocation of attention to the extent that engaging in conversation does. The mean RT for condition B (radio) was 408 ms, just 4% greater than the control condition (392 ms), and the difference was not statistically significant. This finding raises doubt about the accurateness of statements made by cellular phone industry representatives who contend that
‘phones constitute no more of a distraction to drivers than car radios’ (Stein et al., 1987). In fact, conversing on a phone ‘phones constitute no more of a distraction to drivers than other secondary tasks, and whether the use of phones is significantly more distracting to drivers than other secondary tasks, and whether the distraction poses increased accident risk.

4.5. Limitations and conclusions

Our study had three principal limitations. The first concerned the focus on young adults (participants were 18–27 years of age), which prevents generalization of findings to middle-aged or older adults. Second, like previous studies that have used simulation to examine effects of concurrent cellular phone use on driving performance and subsequently, identified interference, determining the implications for real world driving is problematic. However, as already stated, the potential relevance of increased RT in braking for traffic safety is easily inferred. Interference that causes increased RT in braking, such as that potentially generated by engaging in a paced conversation generates significantly more capacity interference than does listening to music.

Therefore, confidence in the data as an accurate reflection of braking performance is warranted.

In summary, the study’s findings supported previous research that found cellular phone use to slow RT in a braking response, and extended earlier work to determine that the effect is the same for hand-held and hands-free phones. Notably, the study also established that a paced conversation with a passenger slowed RT virtually as much as a phone conversation did. We can conclude that some capacity interference is inevitable under conditions of paced-conversing, regardless of whether the conversation occurs via a phone or in-person. Of course, there remains much to learn about whether the use of phones is significantly more distracting to drivers than other secondary tasks, and whether the distraction poses increased accident risk.

References


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