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The Effects of Text Messaging During Dual-Task Driving Simulation on Cardiovascular and Respiratory Responses and Reaction Time

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Abstract. Research over the past decade has shown the potentially harmful effects of distracted driving, particularly on reaction time of the driver to external stimuli. With the recent surge in frequency of the use of cell phones for text messaging in nearly all situations, including during driving, it is important to understand the impact of texting on driver reaction time and the body's physiological response. This study attempts to replicate the effects of text messaging distractions on reaction times found in previous studies, and correlate both physiological and cognitive stress in dual-task situations as measured by changes in cardiovascular and respiratory function and reaction time. Forty subjects completed computerized reaction time tests in single-task (no texting) and dual-task (texting) conditions with heart and respiratory rates manually measured before and after each test. Results showed that text messaging significantly increased reaction time ($p < 0.05$, N=40), heart rate ($p < 0.05$, N=40), and respiratory rate ($p < 0.05$, N=40) in the dual-task environment. The increase in reaction time represents a decrease in mental output, which can be attributed to increase in cognitive workload and stress. This is indicative of decreases in attention and perception of stimuli. The increase in cognitive demands is supported by the increases in heart and respiratory rates, which are physiological responses to stress. While this study affirms the notion of text messaging as a possibly dangerous distraction that elicits a total body physiological stress response, more research needs to be done in natural driving settings to support its observations.

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INTRODUCTION

Driving a motor vehicle requires both applying learned physical skills and executing complex mental processing involving sensory, analytical, and motor functions. There is a limit to how much sensory information the brain can perceive and process at a given time. When an observer visually detects a target within a rapid succession of stimuli, there is a short period of time (approximately between 200-500ms after initial target detection) during which the perception of subsequent targets is impaired, in a phenomena known as the "attentional blink" or AB (Vogel and others 1998). Furthermore, it has been suggested that event-related neural potentials observed during the AB cause complete suppression during a stage of the AB believed to represent "updating of working memory" (Vogel and others 1998). When subsequent visual targets come from a different category than the initial target, i.e., letters instead of numbers, the trailing targets require longer to process or are not processed at all (Di Lollo and others 2004). This inefficiency has been proposed to be a result of the trailing targets not matching the configuration of the input filter for the incoming stimuli, and furthermore, the filter becomes disrupted and takes longer to process subsequent stimuli from the original target's category (Di Lollo and others 2004). This would imply that attempting to process visual information from two drastically different stimuli at the same time, e.g., the visual stream seen through the windshield of a car while driving and the text on a mobile phone while texting, would reproduce the delays and/or errors in processing seen during the AB.

The AB was originally described using stimuli and targets within the central field of vision. Other errors in perception, processing, and response may occur when targets exist in multiple fields of vision, as is common with distracted driving. A Peripheral Detection Task (PDT), a simulation test where the driver is asked to respond to objects in the periphery of their visual field while completing a distracting task, was utilized to compare mental capacity during visual distraction while driving, using reaction time (RT) as a measure of the magnitude of distraction (Olsson & Burns 2000). It showed that RT was significantly slower during distraction (i.e. changing CD or tuning radio) when targets were introduced which required timed responses in the visual periphery. This study did not measure any other variables of driving performance, such as maintaining speed, lane positioning, and visual attention to the road. However, more recent studies show that the use of the hands to adjust radios (Horberry and others 2006), navigation systems (Tsimhoni and others 2004), and DVD players (Hatfield & Chamberlain 2005) negatively impact such measures of driving performance.

The focus of this study is on cell phone use, specifically for text messaging, as a driving distraction. The use of cell phones has become nearly universal, estimated at over 5.98 billion subscribers worldwide (International Telecommunications Union 2011), and likewise the use of cell phones while driving is becoming more and more widespread, with only 3% of adults claiming they never answer a phone call while driving (Tison and others 2011). Simply conversing on a cell phone, even when using a hands-free device, creates an internal context of attention that disrupts the driver's perception of objects in the visual field. This is evidenced by decreased memory and recognition of objects as "old" that had been encountered during driving simulation (Strayer and others 2003). Text messaging has also been shown to impair driving during simulation by increasing RT to brake lights by nearly 0.2 s and decreasing forward and lateral vehicle control (Drews and others 2009). Hosking and others (2009) also found that texting during driving simulation limited lateral vehicle control and increased time spent not looking at the road by nearly 400%.

These studies show that not only is visual perception inhibited by the limits of AB, but also that visually and mentally distracting tasks, particularly the use of cellular and media devices put stress on the central nervous system and reduce the brain's ability to react to target visual stimuli, thus reducing output capacity as is evidenced by increases in RT. Mental stress can also affect other

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bodily systems, such as cardiovascular function via sympathetic neural activity. A mentally stressful task (i.e., mental arithmetic) induces dramatic increases in mean arterial pressure (MAP) and heart rate (HR) (Carter and others 2002, Carter and others 2008). Sending and receiving text messages produces similar mental stress. Monitoring respiration rate (RR) and HR of college students that were comfortable with text messaging showed that sending messages in a normal setting increases both HR and RR, while receiving messages increases HR alone (Lin & Peper 2009). While HR and RR have not been tested during dual-task conditions of driving simulation and text messaging, HR (Collet and others 2009, Reimer and others 2010) and RT (Collet and others 2009) increased significantly during dual-task conditions of driving simulation and hands-free cell phone conversation versus the single-task condition of driving simulation.

The first objective of the current research attempts to affirm the findings of Drews and others (2009) on the impact of text messaging as a cognitive distraction during driving simulation. The second objective is to build on the evidence of the effect of mentally demanding tasks on cardiovascular (Carter and others 2002, Carter and others 2008, Collet and others 2009, Lin & Peper 2009, Reimer and others 2010) and respiratory function (Lin & Peper 2009), culminating in the establishment of a physiological connection between text messaging as a cognitive dual-task distraction with cardiovascular and respiratory effects via sympathetic neural activity. We hypothesize that the dual-task condition of text messaging during driving simulation will produce cognitive demands significant enough to decrease mental output capacity, measurable through increases in reaction time, and that it will produce related cardiovascular and respiratory changes to further support the notion of text messaging increasing cognitive stress during dual-task situations.

METHODS

Subjects

The 40 subjects in this IRB approved study were students at Ohio Northern University between the ages of 18 and 22 who used their cell phones daily for texting purposes. All subjects refrained from caffeine and alcohol consumption for a minimum of 24 hours prior to testing.

Single Task Reaction Test

During the RT test (http://getyourwebsitehere.com/jswb/rttest01.html), each subject was seated in the testing room in front of a monitor showing a stoplight. Each was seated with both hands next to but not touching the computer mouse and forearms resting on the desk. The subject would click the mouse each time the stoplight changed from red to green. Subjects would then reposition their arms to the original position. The test allowed for five RT trials to be taken consecutively over the course of approximately one minute with random rest intervals as determined by the test. The test then automatically calculated mean RT in seconds (s), which constituted each subject's single-task (ST) RT.

Dual Task Reaction Test

After a five-minute rest period, subjects repeated the RT test with dual-task conditions. Each participant was seated with forearms resting in the same manner, but with both hands holding their phone next to but not touching the mouse. A typed sheet of paper with questions asking for the participant's full name, age, address, and contents of last meal was taped to the top of the computer screen, but not obstructing the participant's view of the stoplight. This position simulated the shift in visual attention a driver would experience while attempting to text and drive. Participants were not allowed to read the questions prior to testing. Once the test began, subjects were to read the questions and respond to as many as possible in a texted message while maintaining visual focus on his or her phone while texting. This was done while simultaneously completing the RT test, requiring participants to remove one hand from the phone to click the mouse in response to stimuli. Again, five RT trials were taken and the mean RT recorded as his/her dual-task (DT) RT. Mean RT for all participants in ST and DT conditions were compared using an unpaired two-tailed t-test (α=0.05, N=40).

Physiological Response Measurements

Prior to ST testing conditions, each participant's radial pulse as a measure of resting HR (beats per minute) and RR (breaths per minute, as counted by an observer) were measured manually while seated in the testing station. Immediately following the ST test and with participants still seated at the testing station, HR and RR were measured again, and the change in rates from resting to post-test were averaged, representing mean change in HR and RR, respectively, for ST conditions. After the five-minute rest period, this protocol for recording resting and post-test rates and calculating mean change was repeated for DT conditions. Mean changes in HR and RR between ST and DT conditions were compared using separate unpaired two-tailed t-tests (α=0.05, N=40).

RESULTS

Reaction times significantly ($p < 0.05$, N=40) increased from a ST environment (0.51 ± 0.41 sec) without texting to a DT environment (1.22 ± 0.36 sec) with texting (Figure 1). Similar

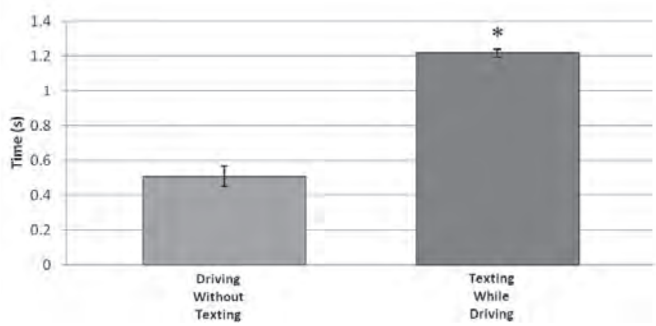

FIGURE 1. Comparison of mean reaction time during simulated driving with ST (no texting) versus DT (texting) conditions. The * indicates a significant difference (α=.05, p=5.731x10^{-16}, N=40).

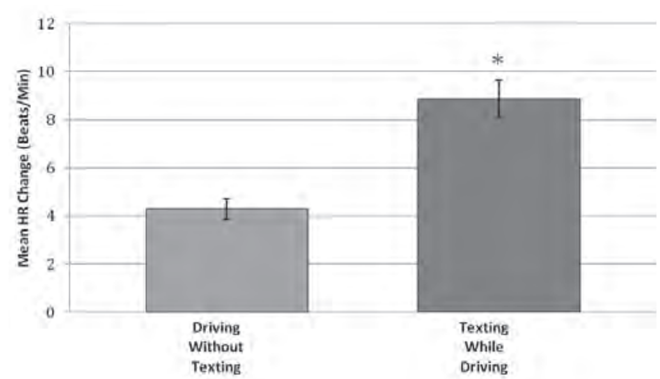

FIGURE 2. Comparison of mean heart rate change during simulated driving with ST (no texting) versus DT (texting) conditions. The * indicates a significant difference (α=.05, p=1.10x10^{-3}, N=40).

significant ($p < 0.05$, N=40) increases in HR (Figure 2), from ST (4.30 ± 2.77 bpm) to DT (8.85 ± 4.99 bpm), and RR (Figure 3), from ST (1.88 ± 1.77 rpm) to DT (3.70 ± 2.90 rpm), were demonstrated.

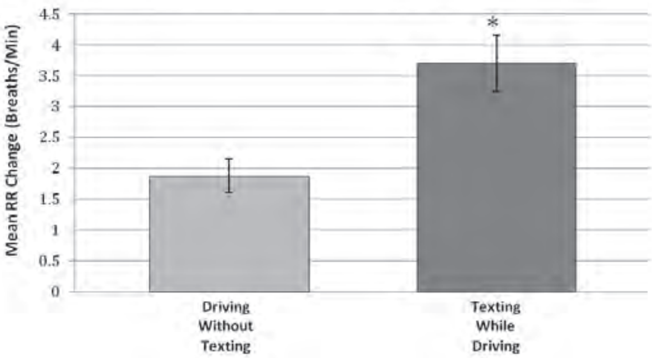

FIGURE 3. Comparison of mean respiration rate change during simulated driving with ST (no texting) versus DT (texting) conditions. The * indicates a significant difference (α=.05, p=1.10x10^{-3}, N=40).

DISCUSSION

The significant increase in reaction time observed during dual-task conditions is indicative of decreases in attention, perception, integration, and reaction. This can be attributed to an increase in overall cognitive workload and added cognitive stress. While supporting the reaction time findings of Drews and others (2009), the observed increase was much more drastic at over 300% greater than that of the previous study, possibly explained by differences in protocol and equipment. The results of Drews and others (2009) were obtained without standardizing or recording hand placement. The current study required that hands and cell phones were placed on the desk, thus ensuring that the target stimuli of the reaction test were in the visual periphery of the participants when their attention, as instructed, was allocated to typing text messages. This affirmed the visual periphery findings of Olsson and Burns (2000). Sometimes drivers text and drive with the phone in both hands and the base of both palms resting on top of the steering wheel, thereby attempting to keep the text screen in the same field of vision as target stimuli seen through the windshield. The current study did not test this scenario. It is believed that increases in reaction time would still exist due to the attentional blink (Vogel and others 1998), particularly because the stimuli would come from different categories (Di Lollo and others 2004).

The current study shows that the dual-task conditions generated enough cognitive stress on the participants to not only reduce output capacity in the form of increased reaction times, but also to warrant a physiological response and recruitment of cardiovascular and respiratory activity to assist with the increase in stress. The current study supports the findings of others (Reimer and others 2010, Lin & Peper 2009, Collet and others 2009, Carter and others 2008, Carter and others 2002). As mental demands increase, a change in physiological response occurs. Sympathetic neural functions react to increase cardiovascular and respiratory activities to supply the brain with its metabolic demands to handle the added stress. Increases in heart and respiratory rates coinciding with the increases in reaction times for dual-task conditions can be attributed to an increase in cognitive stress and workload.

One limitation of the study is the lack of additional measures to assess the impact of the dual-task conditions on attention and vehicle control, such as the use of eye-tracking technology or an actual driving simulation to monitor speed and lane position. In addition, electroencephalography or electromyography might be more accurate than reaction times in measuring increases in cognitive stress and workload, but the inherent effects on participants caused by the use of such equipment and testing would have to be taken into account. Another limitation of the study was the requirement of participants to text responses to questions that were typed on paper rather than received on the phones, in addition to the questions not requiring extensive critical thinking to answer. More research needs to be completed on the cognitive and physiological effects of text messaging in a more natural setting in order to further support the observations of this study. Additional research possibilities include comparing the results of the current study to results of a future study involving older participants who are perhaps less experienced with texting and more experienced with driving.

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