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Text-speak processing impairs tactile location

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ABSTRACT

Dual task experiments have highlighted that driving while having a conversation on a cell phone can have negative impacts on driving (Strayer & Drews, 2007). It has also been noted that this negative impact is greater when reading a text-message (Lee, 2007). Commonly used in text-messaging are shortening devices collectively known as text-speak (e.g.,**Ys I wll ttyl 2nite**, Yes I will talk to you later tonight). To the authors' knowledge, there has been no investigation into the potential negative impacts of reading text-speak on concurrent performance on other tasks. Forty participants read a correctly spelled story and a story presented in text-speak while concurrently monitoring for a vibration around their waist. Slower reaction times and fewer correct vibration detections occurred while reading text-speak than while reading a correctly spelled story. The results suggest that reading text-speak imposes greater cognitive load than reading correctly spelled text. These findings suggest that the negative impact of text messaging on driving may be compounded by the messages being in text-speak, instead of orthographically correct text.

1. Introduction

A driver of a vehicle today is provided with an array of new technologies not seen in past generations. These include music and DVD players, global positioning systems and interactive communication devices such as cell phones. Although these new technologies afford the driver entertainment and convenience, they come at a cost. Physical operation of these technologies and holding a conversation have negative impacts on driving (e.g., Briem & Hedman, 1995; Brookhuis, De Vries, & De Waard, 1991; Hatfield & Chamberlain, 2005; McEvoy et al., 2005; Strayer, Drews, & Johnston, 2003; Tsimhoni, Smith, & Green, 2004). Talking on a cell phone is cognitively demanding, which can cause a form of inattentional blindness (Strayer & Drews, 2007). One consequence of involvement in conversation with an absent person is impaired awareness of important features of the driving environment: drivers miss critical signals (e.g., break lights or road signs) which can have dire consequences (Strayer et al., 2003; Strayer & Johnston, 2001). This may appear surprising because the acts of listening and speaking do not themselves involve the eyes or looking. Demanding cognitive activities appear to impair our ability to respond to important signals regardless of the sensory modality involved.

Recently, text messaging has become a popular means of communication (Crystal, 2008). Although a small country, New Zealand has a significant number of cell phones in use (4.6 million) (CIA, 2008) and over a million text messages are sent daily (Bramley et al., 2005). This popularity of text messaging is mirrored worldwide (Rheingold, 2002). Undoubtedly, talking on a cell phone has detrimental effects on driving ability (Strayer, Drews, & Crouch, 2006). However, other forms of distraction such as text messaging have been found to be even more distracting (Lee, 2007).

Text messaging evokes competition for resources between visual, manual, and cognitive processing (Head, Shears, Neumann, & Helton, 2011; Hosking & Young, 2009; Knott, Nelson, Brown, Dukes, & Bolia, 2007). Indeed, reading and responding to a text message is visually demanding and causes drivers to take their eyes off the road which can result in negative consequences (Hosking & Young, 2009; Lansdown, 2001; Wierwille & Tijerina, 1998). Moreover, the physical demand of key presses requires the driver to take one or both hands off the steering wheel, which is also dangerous (e.g., Reed & Green, 1999). Collectively, these studies indicate that text messaging is visually and physically demanding; however, they do not examine the possible central cognitive demands involved in processing text messages.

Maintaining attention is subject to a finite amount of mental resources (Helton & Russell, 2011a; Navon & Gopher, 1979). Multiple resource theory (MRT) proposes that different pools of mental resources exist and are modality-specific (Kantowitz & Knight, 1976; Wickens, 1976, 1984, 2002). Thus, if an individual is presented with two stimuli in different modalities (e.g., visual and auditory) there should be less resource drain because they do not overlap (Wickens, 2008). Conceivably, this modality-specific processing is likely due to neuro-cortical specificity. Indeed, behavioural and neurophysiological

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studies have highlighted that tactile, word, and spatial processing occur in different cortical regions of the brain (Fiez & Peterson, 1998; Giabbiconi et al., 2007; Karnath, Ferber, & Himmelback, 2001; Martinovic, Gruber, & Müeller, 2007; Peterson, Fox, Posner, Mintun, & Raichle, 1988; Price, 2000; Price, Wise, & Frackowiak, 1996; Pugh et al., 1996; Snyder, Abdullaev, Posner, & Raichle, 1995; Turkeltaub, Eden, Jones, & Zeffiro, 2002; Vandenberghe, Nobre, & Price, 2002). Nevertheless, cognitive task demand or 'mental workload' may have modulating effects on resource allocation (Wickens, 2008).

Given limited space or time to convey a message, people often incorporate shortening techniques to present meaningful content with less bits of information. For example, people use subsets (**txt**, text), shortcuts (**gr8**, great), phonetic respellings (**cya**, see you) and acronyms (**ttyl**, talk to you later) to convey messages in a shorter amount of time and space. Collectively, these shortening techniques above are known as text-speak (see Kul, 2007 for further examples). For individuals who are literate, word recognition is automatic (Stroop, 1935), and captures attention (Johnston, Hawley, Plewe, Elliott, & DeWitt, 1990). Conversely, prior research has established that presenting words in text-speak (e.g., **ys I wll ttyl 2nite**, yes I will talk to you later tonight) is not as automatic and does not capture attention as efficiently as correctly spelled words (Head, Helton, Neumann, Russell, & Shears, 2011). Additionally, text-speak words are less semantically meaningful (Head et al., 2011), and are more difficult to relate to sentence context (Head et al., submitted for publication) than orthographically correct words. Collectively, text-speak appears to induce greater mental workload than correctly spelled words.

In the current investigation, we focused on the processing of text-speak stories, in contrast to correctly spelled stories, while participants concurrently monitored for vibrations in a secondary task. Although our design does not examine driving performance, it allows us to isolate the effects of text-speak cognitive processing from text messaging's visual and motor demands in a controlled setting. As alluded to above, monitoring vibrations on the body and reading text are non-overlapping modalities and should be processed by different cortical brain regions. Thus, according to Wicken's multiple resources theory (Wickens, 2008), performance decrements (increased reaction times decreased accuracy, or both) should be attributed to the consequences of shared higher-level cognitive resources (those central or executive processing resources shared across modalities).

Does reading text-speak stories produce more errors in a secondary task relative to reading correctly spelled stories? The following predictions are tested: First, compared with a single task vibration detection situation, detection of tactile vibrations will fall and detection times will increase in a dual task where participants simultaneously read a passage for meaning. Second, there will be a greater decline in detection performance when reading text-speak passages compared to reading correctly spelled passages. Third, following Head et al., 2011, the disruptive effects on vibration detection when reading text-speak will be less pronounced in participants who report more willingness to use text-speak. Finally, it is predicted that reading text-speak will result in lower reading comprehension scores than correctly spelled stories.

2. Methods

2.1. Participants

Forty right-handed University of Canterbury students (26 women and 14 men, M age = 21 yrs, SD = 5 yrs) participated in the experiment for course credit. All participants were native English speakers and had normal or corrected to normal vision.

2.2. Apparatus & materials

2.2.1. Tactile stimuli

Presentation and timing of visual and tactile stimuli and response accuracy and timing were achieved using E-prime Professional 2.0 (Schneider, Eshman, & Zuccolotto, 2002). For the vibration task, participant responses were measured to millisecond precision by a serial response mouse. Each participant was outfitted with a tactile stimulation belt that was worn around their abdomen. The adjustable elastic belt consisted of eight EAI model C2 Tactors (Engineering Acoustics, Inc, Winter Park, FL) although only two tactors were used. The 17 g (30 mm diameter by 7.9 mm height) tactors utilize a center-surround design that enables a 7.6 mm plunger-like contactor to generate precise localized stimulation. This provided sinusoidal vibrations to the skin at 250 Hz.

2.2.2. Reading passages

Two stories[1] were selected and matched for word length and level of reading difficulty (Flesch, 1948). Subsequent text-speak versions of each story were created by substituting correctly spelled word forms (e.g., *tonight*) with text-speak versions (e.g., *2nite*) when possible. Text-speak stories were controlled for number of substitutions and shortening techniques (Choudhury et al., 2007; Crystal, 2008; Head et al., 2011; Plester, Wood, & Bell, 2008). On average for both stories, 60% of the words were text-speak representations and 40% were correctly spelled. The 40% correctly spelled accounted mostly for conjunctions (e.g., but, or, & yet) and articles (e.g., a, an, & the). Given that the participants were from New Zealand, we used text-speak representations from the New Zealand text-speak norm database (Head et al., unpublished manuscript).

2.2.3. Text-speak questionnaire

The text-speak questionnaire (Head et al., 2011) is an 8 item self-report questionnaire that consists of 3 factors: willingness to use text-speak, text messaging experience, and preference to use text messaging. This questionnaire has been used in previous studies and has successfully correlated text-speak willingness with behavioural performance (Head et al., 2011; Head, Russell, Dorahy, Neumann, & Helton, 2012). The willingness to use text speak factor consists of 3 items directly addressing self-reported experiences of using text-speak in texting: (1) I always use acronyms (got to go-gtg) when text messaging, (2) I always use subsetting (Text-Txt) when I send a text message) and (3) I always use predictive text when I use my cell phone (reverse scored). This is a separate text-speak specific aspect of texting, than for example, overall texting frequency.

2.3. Procedure

Upon arrival, participants were given an overview of the study and requested to read and sign an informed consent form. Participants were screened during the practice trial for tactile sensitivity which resulted in one participant being excluded from the study. All participants wore a 198 g 100% black cotton t-shirt to ensure standardization of the material between the tactors and the skin (Brill, 2007). The vibrotactile belt was worn approximately 25 mm above the navel. A circumference measurement around each participant was taken on the abdominal plane above the iliac crest. This measurement allowed us to place the tactors at approximately equal lateral distances from the naval midline on the left and right side of the body (Brill, 2007; Cholewiak, Brill, & Schwab, 2004).

Participants were seated 50 cm in front of a 32.5×24 cm CRT Compaq S720 monitor at approximately eye level. Their heads were not restrained in any way. For the vibration task participants were instructed to press the left button of the serial mouse with the index finger of their right hand whenever a vibration occurred on the left side of their body and with the middle finger of their right hand to vibrations occurring on the right side of their body. They were instructed to make responses as quickly as they could without

[1] Stories were selected and augmented from http://legacy.lclark.edu/~krauss/toppicks/reading.html?.

making errors. The 250 Hz vibrations lasted 100 ms and were followed by a 1000 ms interval during which responses were accepted and recorded. Responses after the 1000 ms interval were recorded as misses. During single task vibration only trials (VOT) and dual task conditions, vibrations occurred at the rate of 55 stimuli per minute and continued for 6.28 min.

In dual task conditions participants were informed that they needed to read and comprehend a story while at the same time responding to vibrations that occurred on the left or right side of their torsos. They were also informed that they would be tested on their understanding of the story at a later time. The story passages were presented using the Rapid Serial Visual Presentation (RSVP) method that is commonly used in reading research (Bernard, Chaparro, & Russell, 2001; Juola, Tiritoglu, & Pleunis, 1995; Rahman & Mutter, 1999). Words or text-speak abbreviations were presented one at a time in the centre of the screen at the rate of one item every 500 ms (i.e.,120 words per minute). This presentation rate was chosen because extensive pilot work revealed this was the minimum rate necessary for comprehension of text-speak, which is known to take longer to read than normal text (Head et al., 2011; Knott et al., 2007; Reilly & Radach, 2006; Salvucci, 2001). RSVP was favoured because it prevents the influence of spatial attention shifts between visual and tactile modalities (Spence, Pavani, & Drier, 2004). During dual task trials the start time for the first vibration stimulus was varied so that the vibrations did not coincide with the onset of words or text-speak items. For example, as the first word was being shown (500 ms), the vibration could either commence at 100 ms, 200 ms, or 300 ms during the first word presentation. To accomplish this Eprime randomly assigned each individual to one of 3 delays (e.g., 100 ms, 200 ms, 300 ms) on the onset of each dual task. This was done to discourage participants from using word onset from the RSVP task as a visual cues for the initial vibration occurrence and to stagger their appearance throughout the task. The tactile task across participants; however, occurred with a constant inter-stimulus interval (ISI).

Participants completed one VOT block followed by two dual task blocks (reading with intermittent concurrent vibration) and then a second block of VOT trials. Prior to each experimental block, participants performed VOT trials for approximately one minute and were given accuracy feedback. They also completed a 2 min long dual reading and vibration detection practice session to familiarize them with the RSVP method of presentation and the requirements of the dual task. Text-speak and correctly spelled dual tasks were preceded with a text-speak and correctly spelled dual task practice, respectively. Participants received visual accuracy feedback during the dual task practice trials only. Participants were instructed to read for comprehension and respond to vibrations as fast and accurately as permitted. The entire experimental session lasted approximately 40 min.

2.4. Design

The experiment entailed a within-subject design. Each participant was presented with VOT pre and post dual task conditions. Each participant completed a dual task with a story presented as text-speak and correctly spelled. The order of stories and whether they were presented as text-speak or correctly spelled were counterbalanced between participants.

3. Results

3.1. Reaction time

Response times greater than 1000 ms and less than 200 ms were excluded from reaction time analysis to reduce the likelihood of outliers as recommended by Ratcliff (1993). Response times for the first and second VOT blocks were averaged. A one-way repeated measure ANOVA on correct responses was conducted to compare reaction times for the three conditions: VOT, dual task with correctly spelled words and dual task with text-speak. There was a significant overall effect, $F(2, 78) = 11.14$, $p < .001$, $\eta^2_p = .22$ (see Fig. 1). Orthogonal contrasts (Keppel & Zedeck, 2001) indicated that the location responses were faster for single task VOT trials ($M = 278$ ms; $SD = 55.9$) than dual task reading and vibration conditions, $F(1, 39) = 13.43$, $p = .001$, $\eta^2_p = .26$. Further, location responses were faster when reading correctly spelled ($M = 311$; $SD = 63.6$) than text-speak passages ($M = 322$; $SD = 64.9$), $F(1, 39) = 4.15$, $p = .05$, $\eta^2_p = .01$.

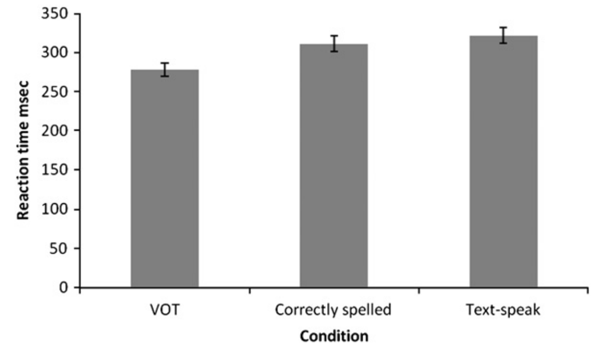

Fig. 1. Reaction times for correct responses for VOT, correctly spelled, and text-speak conditions; error bars depict standard error of the mean.

3.2. Correct vibration responses

Probability of correct vibration location responses for the three conditions is presented in Fig. 2. A one-way repeated measures ANOVA was conducted on arcsin transformed (Kirk, 1995; Maxwell & Delaney, 2004) proportion correct vibration responses for the VOT, and two dual task conditions. The overall effect was significant, $F(2,78) = 52.88$, $p < .001$, $\eta^2_p = .576$ (see Fig. 2). Orthogonal contrasts indicated that the proportion of correct vibration responses was significantly higher for the VOT ($M = .94$; $SD = .06$) than dual task conditions, $F(1, 39) = 81.91$, $p < .001$, $\eta^2_p = .68$, and that the proportion of correct vibration responses was significantly greater when reading correctly spelled passages ($M = .88$; $SD = .08$) than text-speak passages ($M = .86$; $SD = .11$), $F(1, 39) = 7.78$, $p = .008$, $\eta^2_p = .17$.

3.3. Missed responses

The proportions of occasions where vibration location responses did not occur within the 1000 ms response window are presented in Fig. 3. A one-way repeated measures ANOVA was conducted on arcsin transformed missed responses for the VOT, and dual task conditions. There was a significant overall effect, $F(2,78) = 26.81$, $p < .001$ $\eta^2_p = .41$. Orthogonal contrasts indicated that failure to respond to vibrations occurred less often in the VOT condition ($M = .02$; $SD = .03$) than in the dual task conditions ($M = .07$; $SD = .08$), $F(1, 39) = 42.94$,

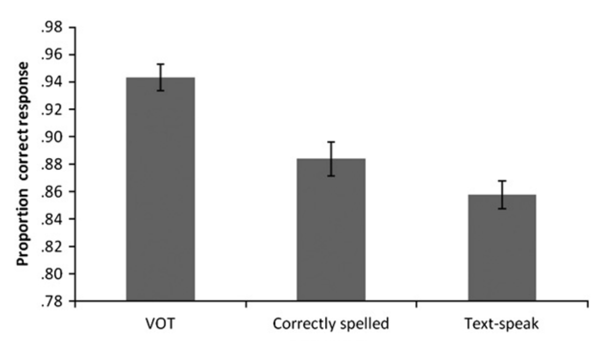

Fig. 2. Proportion of correct responses for baseline, correctly spelled, and text-speak conditions; error bars depict standard error of the mean.

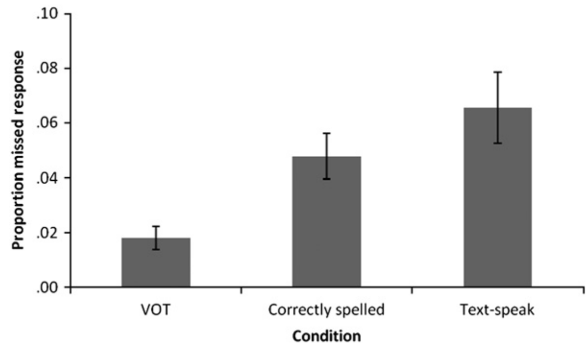

Fig. 3. Proportion of missed responses for baseline, correctly spelled, and text-speak conditions; error bars depict standard error of the mean.

$p<.001$, $\eta^2_p = .524$. However, vibrations were missed equally when reading correctly spelled stories and those in text-speak (see Fig. 3).

3.4. Relationship between performance metrics and self-reported text experience

Gender and age did not yield any significant correlations with participants' accuracy or reaction time in either of the dual tasks. We correlated each participant's correct response time in the text-speak dual task with the willingness to use text-speak factor derived from the questionnaire. This correlation was negative and statistically significant $r(39) = -.313$, $p = .05$). Thus, as self-reported willingness to use text-speak increases response time decreases. To verify that those who report being more willing to use text-speak were not just generally faster overall; we correlated those participants' correct reaction time with the correctly spelled dual task, but it was statistically non significant ($r(39) = -.203$, $p = .21$). No other correlations with the behavioural performance data were significant and thus are not reported.

3.5. Reading comprehension assessment

Participants completed a 10-item true/false reading comprehension assessment for the correctly spelled and text-speak stories. The proportion correct was calculated for each assessment and was then arcsine transformed as recommended (Kirk, 1995; Maxwell & Delaney, 2004) prior to analysis (see Fig. 4). A *t*-test revealed no difference in reading comprehension scores for correctly spelled stories ($M = .84$; $SD = 2.34$) and stories written in text-speak ($M = .80$; $SD = 2.62$), $t(39) = 1.30$, $p = .23$.

4. Discussion

This study examined whether reading stories presented in text-speak is more resource demanding than reading the same stories correctly spelled. Participants completed a dual task where they reported the laterality of a brief vibration on their torso while concurrently reading a story presented as text-speak or as correctly spelled words. Compared to a single task vibration only condition, accuracy and speed of reporting the location of vibrations was considerably reduced when participants concurrently read a story. Importantly in the present context, speed and accuracy of vibration location responses was impaired more when reading text-speak compared to correctly spelled versions of the same stories. Crucially, the dual task employed was sensitive in distinguishing differential cognitive demands between correctly spelled and text-speak stories presented in the dual tasks. The text-speak questionnaire was successful in showing a relationship between self-reported willingness to use text-speak and behavioural results.

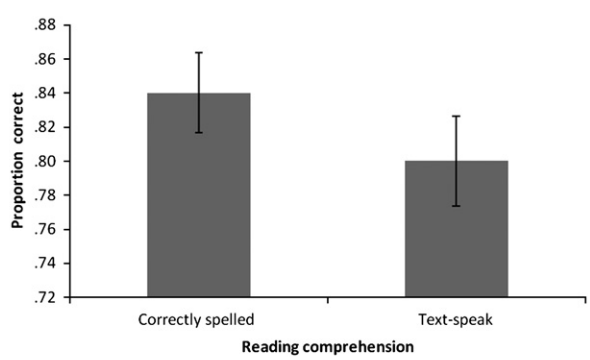

Fig. 4. Proportion correct for comprehension assessment for correctly spelled and text-speak conditions; error bars depict standard error of the mean.

Analogous to Strayer and Drews (2007) findings, a participant engaged in two tasks of non-overlapping modalities (visual and tactile) can still undergo a form of inattentional blindness, resulting in missed critical signals. Further, our results show that a form of inattentional blindness to critical signals is not modality specific to auditory stimuli paired with visual, but also when tactile stimuli are paired with visual. Maintaining attention is thought to be subject to a limited amount of resources (Green & Helton, 2011; Helton & Russell, 2011b; Navon & Gopher, 1979). Within our study we have two tasks (reading and tactile monitoring) competing for attention resources. As stated above, word recognition demands attention (Johnston et al., 1990; Stroop, 1935). Therefore, missed critical signals within the tactile portion of the dual task can be attributed to the appropriation of mental resources to the reading task. Indeed, this could be due to the reading task being more contextually engaging than the tactile task.

According to the MRT, multiple resource pools exist and are modality-specific for processing information. Therefore, processing two stimuli of different modalities should cause less resource depletion relative to processing the same stimuli within the same modality. Participants' performance during the dual task was significantly hindered compared to the VOT, suggesting that the activities of reading and monitoring for vibrations are competing for the same resource pool. However, since they are in different sensory modalities (visual vs. tactile) and one is verbal (reading) and the other spatial (vibration location) the shared resources are presumably at a higher cognitive level (see Helton & Russell, 2011a). Wickens (2008) suggests if mental workload is high, then greater mental resource depletion can occur. Indeed, this may be because the task is novel. It has been noted that completing a novel task can increase mental workload (Hancock & Meshkati, 1988). For those who are literate, reading is not considered a novel task; however, monitoring and responding to a vibration is likely to be novel for most participants. The reading and vibration task coupled into a combined endeavour appears to increase mental workload, which thus increased mental resource demand.

The vibration detection task and the reading task were in separate sensory modalities, which should interfere less than two tasks in the same modality (for example, driving and texting). The vibration detection task was spatial, and the reading task was verbal. These two tasks should interfere less than two spatial tasks (for example, driving and orienting on a map). The vibration detection task required a simple manual response and the reading task required no manual response (not until later with the reading comprehension test). These two tasks should interfere less than two tasks requiring a manual response (like driving and texting). The vibration task was relatively simple, two alternative forced choice, with clear response mapping (right to right, left to left) and a constant ISI. Even though every effort was taken to minimize the interference effect between the two tasks, there was still greater dual-task interference for the text-speak than the orthographically correct text task. We expect that even though the size of our effect is small in this study, the additional demand of text-speak processing could be a contributory factor in a snowballing effect and thus, larger effect, in a more realistic scenario where the two tasks may overlap greater in resource demands. This requires further research.

Text-speak representation allows an individual to present a word in a shorter amount of time and space (Head et al., 2011). However, if the reader of the word is less confident about using text-speak, additional mental workload may be needed (Head et al., 2011, submitted for publication). Indeed, the negative correlation between the willingness to use text-speak factor and reaction time suggests that if an individual is more willing to use text-speak, then less mental workload is placed on that reader, which equates to less mental resource demand.

Interestingly, our reading comprehension scores failed to show a statistically significant negative impact of reading a story in text-speak in comparison with reading a correctly spelled story. To insure that participants could comprehend text-speak words, we used longer word durations based on piloting. As pointed out by an anonymous reviewer, slower word presentation may have oversimplified the task, which may explain why participants did not differ on the comprehension test. Indeed, a faster word presentation may better demonstrate the cost of processing text-speak relative to correctly spelt. Nevertheless, the behavioural data did show a performance decrement to vibration monitoring when participants were reading text-speak. Thus, the higher than expected reading comprehension scores for the text-speak story can be attributed to a performance comprehension trade-off (see Head et al., 2011). In other words, in order for someone to achieve the higher than expected reading comprehension scores for text-speak, reaction time and accuracy are sacrificed on the vibration task to facilitate comprehension of the story.

This study demonstrated that presenting stimuli in different modalities induces elevated cognitive resource demands. Although our study does not include assessments of driving performance per se, it nevertheless has implications for any tasks combined with reading text-speak. We showed in a controlled setting that reading stories in text-speak increases performance decrements relative to reading correctly spelled stories. The applied implication of the results is that reading text messages while driving is extremely dangerous in its own right; however, this danger can be compounded further if the driver is reading messages in text-speak. Indeed, processing non-overlapping modalities (tactile vs. visual) should produce relatively less interference compared to processing overlapping modalities. Thus one would expect far greater interference if trying to watch the road and read a text message while driving. Further research is needed to investigate the effects of text-speak processing in other settings such as driving to better understand the potential cost of reading text-speak while performing other tasks.

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