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The impact of walking while using a smartphone on pedestrians' awareness of roadside events

Ming-I Brandon Lin*, Yu-Ping Huang

Department of Industrial and Information Management, National Cheng Kung University, No.1 University Road, Tainan City 701, Taiwan, ROC

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ABSTRACT

Previous studies have shown that using a cell phone to talk or text while walking changes gait kinematics and encourages risky street-crossing behaviors. However, less is known about how the motor-cognitive interference imposed by smartphone tasks affects pedestrians' situational awareness to environmental targets relevant to pedestrian safety. This study systematically investigated the influence of smartphone use on detection of and responses to a variety of roadside events in a semi-virtual walking environment. Twenty-four healthy participants completed six treadmill walking sessions while engaged in a concurrent picture-dragging, texting, or news-reading task. During distracted walking, they were required to simultaneously monitor the occurrence of road events for two different levels of event frequency. Performance measures for smartphone tasks and event responses, eye movements, and perceived workload and situational awareness were compared across different dual-task conditions. The results revealed that during dual-task walking, the reading app was associated with a significantly higher level of perceived workload, and impaired awareness of the surrounding environment to a greater extent compared with the texting or picture-dragging apps. Pedestrians took longer to visually detect the roadside events in the reading and texting conditions than in the dragging condition. Differences in event response performances were mainly dependent on their salient features but were also affected by the type of smartphone task. Texting was found to make participants more reliant on their central vision to detect road events. Moreover, different gaze-scanning patterns were adopted by participants to better protect dual-task performance in response to the changes in road-event frequency. The findings of relationships between workload, dual-task performances, and allocation strategies for visual attention further our understanding of pedestrian behavior and safety. By knowing how attentional and motor demands involved in different smartphone tasks affect pedestrians' awareness to critical roadside events, effective awareness campaigns might be devised to discourage smartphone use while walking.

1. Introduction

Among the activities of daily living, walking is a basic and common mode of transportation, especially when the movement distance is within several blocks. However, pedestrians are more likely to directly experience high impact forces than road users in vehicles when a traffic accident occurs, and consequently, pedestrians are more susceptible to severe injuries (Pucher and Dijkstra, 2003). In the US, pedestrian fatalities as a proportion of the total motor vehicle fatalities has steadily increased from 11% in 2005 to 15% in 2014, despite a substantial decrease in total traffic fatalities over the past decade (National Highway Traffic Safety Administration, 2016). Several risk factors that could affect pedestrian injury severity or fatality have been cited in the literature (Haleem et al., 2015; Jang et al., 2013), including environmental characteristics (e.g., darkness/lack of illumination, high traffic density), vehicle characteristics (e.g., large vehicles), and pedestrian-related characteristics (e.g., very young or old age, cell phone use, and other risky behaviors).

The Wireless Association suggested that in 2014, more than half of the device connections in North America were smartphones, and these accounted for 77% of the total wireless network traffic (The Wireless Association, 2015). With the advent of mobile technology, smartphones allow users not only to make voice calls and perform text messaging, but also to engage in social networking, gaming, video streaming, and a variety of mobile applications (apps). A recent survey of more than 2000 US adults by the

* Corresponding author.
E-mail addresses: brandonl@mail.ncku.edu.tw, mingilin@gmail.com (M.-I.B. Lin).

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American Academy of Orthopaedic Surgeons (2015) reported that nearly one-third of the respondents admitted to frequently using a smartphone for non-speech activities while walking, whereas 85% stated they had seen others perform these behaviors. Furthermore, 26% of respondents had been involved in distracted-walking incidents, ranging from bumping into something without injury, falling, or experiencing sprains or fractures. Using data from the US Consumer Product Safety Commission on injuries in hospital emergency rooms from 2004 to 2010, Nasar and Troyer (2013) found that the percentage of total pedestrian injuries related to mobile phones steadily increased; in 2010, it exceeded the estimate for drivers. However, unlike distracted driving (Collet et al., 2010; Johannsdottir and Herdman, 2010; Kaber et al., 2012; Recarte and Nunes, 2003; Strayer and Johnston, 2001), there is less published research on the impact of using a smartphone while walking, despite its imminent threat to the safety of pedestrians and other shared-road users.

Several researchers using semi-immersive virtual environments found that individuals tend to exhibit more risky street-crossing behaviors (e.g., less likely to recognize and act on crossing opportunities, pay less attention to traffic, or more likely to look away from the street environment) when either engaging in phone conversation (Neider et al., 2010), listening to a mobile music device (Neider et al., 2010), or texting (Schwebel et al., 2012) than when undistracted. For example, Stavrinos et al. (2011) reported that pedestrians conversing on a phone were less likely than undistracted pedestrians to recognize crossing opportunities, even though the former waited longer curbside. Schwebel et al. (2012) also revealed that participants distracted by texting or music had higher odds of being hit by vehicles in a simulated environment than those who were undistracted. The performance decrements observed in distracted pedestrians are in part due to competition for limited attentional resources between street-crossing behaviors and mobile phone activities (Wickens, 2008). In the primary-secondary task paradigm, secondary task performance was found to be associated with the amount of residual attention available and has been used to assess mental workload (Parasuraman et al., 2008; Young et al., 2015). The multi-dimensional nature of mental workloads also suggests that interferences as the result of dual-tasking could occur at different information processing stages (e.g., detection, discrimination, or motor response) (Recarte and Nunes, 2003) and selectively impair task performance. However, the extent to which visual attention is affected by mobile phone use in distracted walking is not clear due to the lack of detailed information regarding oculomotor responses.

Recent findings from the dual-task literature suggest that walking while performing a task may alter neutral correlates of executive function and dynamic postural control (Hamacher et al., 2015; Lin and Lin, 2016). With a concurrent non-gait task, participants change gait patterns, reduce low-limb joint variability, or experience reduced ability to maintain path direction (Kao et al., 2015; Lamberg and Muratori, 2012; Lin and Lin, 2016; Schabrun et al., 2014). Meanwhile, it has been argued that some modifications of these joint kinematics and spatiotemporal gait characteristics (e.g., wider stride width and greater margins of stability) are protective walking strategies adopted by pedestrians to compensate for the increased stability challenges during dual-tasking (Kao et al., 2015; Schabrun et al., 2014).

In addition to examining pedestrians' behaviors and posture controls during ambulation, it is crucial to understand how distracted walking influences the ability of individuals to maintain awareness of the traffic environment, so as to devise efficient interventions and policies to improve pedestrian safety. Vision has showed to play an important role in guiding anticipatory locomotor adjustments to avoid potential perturbation (Higuchi, 2013). Empirical research indicated that engaging in a mobile phone conversation can cause pedestrians to neglect "out-of-place" objects (i.e., an UNSAFE sign, a boot, a cat, pieces of fake vomit, and a chalk sketch of an ostrich) placed along their walking route (Nasar et al., 2008). Lim et al. (2015) recently investigated the effects of texting on situational awareness during walking and found that the reduced detection of visual cues depended on the nature of the visual information provided. Nevertheless, some popular current activities entice pedestrians to interact with their smartphones, and may tax attentional resources in a manner different from texting or conversing (Rogers, 2016). It remains unknown whether individuals distracted by these smartphone tasks would selectively alter their gaze behaviors to better perceive environmental cues that, if unattended, could place the individual at risk of collision. This gap in the current understanding is particularly pertinent given that individuals who tend to show distracted walking seem overconfident of their multitasking abilities (American Academy of Orthopaedic Surgeons, 2015).

The main purpose of this study was to systematically investigate the effects of smartphone use on the situational awareness of roadside events relevant to pedestrian safety. While walking along a virtual path and performing either a picture-dragging, instant messaging, or news reading task on a smartphone, young participants were instructed to continuously monitor the onset of designated roadside events and discriminate them accordingly. Laboratory-based experiments were designed to allow measurement of performances of both app tasks and event responses, gaze patterns, and perceived task workload and situational awareness across different levels of road event density. We hypothesized that participants would experience unequal levels of task workload and awareness of the traffic environment when engaging in different smartphone tasks while walking. Furthermore, the influence of dual-task walking on the detectability of road events was expected to be more profound for a smartphone task that demanded more attentional resources or induced more cognitive-motor interference. Further, response times to road events were predicted to depend on the stimulus characteristics and to be further affected by traffic density. Finally, we also hypothesized that participants would adopt different strategies of attention allocation to better preserve the desired task performances when the frequency of occurrence of road-events increased.

2. Method

2.1. Participants

Twenty-four healthy young adults (12 males; age = 23.5 ± 1.1 years; height = 168.4 ± 6.7 cm) were recruited from local universities for the study. Individuals were excluded if they had any known neurological or musculoskeletal abnormalities that would limit their ability to walk or text on the touchscreen of a smartphone. This particular age group was chosen as they experience the highest incidence of pedestrian injuries (National Center for Injury Prevention and Control, 2014) and are significantly more likely to report frequent smartphone use while crossing the roads than other age groups (Lennon et al., 2017). All participants were right-handed, had normal or correct-to-normal vision, and had possessed a smartphone for more than one year. Before participation, they provided written informed consent for procedures, which were approved by the Human Research Ethics Committee of the National Cheng Kung University (#103-030-2).

2.2. Instruments

The virtual pedestrian walking environment consisted of a surrounding display formed by two 42" liquid-crystal display