

Effects of mobile texting and gaming on gait with obstructions under different illumination levels

Jaeyun Cha^a, Hyunjin Kim^b, Jaemyoung Park^c, Changho Song^d

^aDepartment of Rehabilitation Medicine, Sahmyook Seoul Medical Center, Seoul, Republic of Korea

^bDepartment of Rehabilitation Medicine, Hanyang University Guri Hospital, Guri, Republic of Korea

^cDepartment of Rehabilitation Medicine, Seoul Medical Center, Seoul, Republic of Korea

^dDepartment of Physical Therapy, College of Health and Welfare, Sahmyook University, Seoul, Republic of Korea

Objective: This study was conducted to test the effects of mobile texting and gaming on gait with obstructions under different illumination levels.

Design: Cross-sectional study.

Methods: Twelve healthy adults aged 20 to 36 years (mean 23.5 years) were tested under six different conditions. All participants used touchscreen smartphones. Testing conditions included: 1) Walking with an obstruction under a bright illumination level; 2) walking with an obstruction with a low level of illumination; 3) walking with an obstruction while texting under a bright illumination level; 4) walking with an obstruction while texting with a low level of illumination; 5) walking with an obstruction while gaming under a bright illumination level; and 6) walking with an obstruction while gaming with a low level of illumination. All participants were asked to text the Korean national anthem by their own phone and play Temple Run 2 using an iPhone 5. Gait variances were measured over a distance of 3 m, and the mean value after three trials was used. A gait analyzer was used to measure the data.

Results: Compared to normal gait with obstruction, gait speed, step length, stride length, step time, stride time, cadence while texting and gaming showed significant differences ($p < 0.05$). Differences between the illumination levels included gait speed, step length, stride length, and step time ($p < 0.05$) with no significant differences in stride time and cadence.

Conclusions: Dual-tasking using a smartphone under low levels of illumination lowers the quality of gait with obstructions.

Key Words: Cell phones, Gait, Task performance, Lighting

Introduction

Mobile phones are used for a significant portion of everyday life in all age groups. Seventy-seven percent of the world's population have mobile phones, and they have been recognized as a cost-effective communication tool [1]. Although mobile phones provide great convenience, they cause risks in certain situations [2]. Pedestrian use of mobile phones increases cognitive distraction, decreases the ability to react to sudden changes, and increases disturbing actions causing injury or even death [3-6]. For example, in a virtual experiment, it was shown that texting while walking in-

creases the chance of being hit by a car or a motorcycle; moreover, texting is a distraction from the surroundings [7]. Previous research on texting while walking has shown that pedestrians walk slower with less traffic awareness [3,5]. The act of texting while walking changes the consciousness of walking affected by the working memory and executive control [8].

In order to write a text, the attention must be focused on a small screen. Because of gaze fixation on the mobile screen, the visual information of the surrounding environment significantly drops [9]. Also, a heightened attention level is necessary while texting for agile hand movements. Atten-

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Corresponding author: Changho Song

Department of Physical Therapy, College of Health and Welfare, Sahmyook University, 815 Hwarang-ro, Nowon-gu, Seoul 139-742, Republic of Korea
Tel: 82-2-3399-1637 Fax: 82-2-3399-1639 E-mail: chsong@syu.ac.kr

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tion is defined as personal processing ability [10], and multi-tasking can be used as a tool to measure the attention level in processing data. Each individual has a limited central processing capacity, which is required in data processing. If multi-tasking exceeds the level of processing capacity, multi-tasking will be affected [11]. As a result, multi-tasking cannot be used as a tool to measure the processing capacity level. Although safe walking requires both physical ability and sensory ability, multi-tasking (such as texting and gaming) disturbs the working memory and causes situational errors [12].

People multi-task most of the time in pedestrian activity. However, even simple multi-tasking causes negative impacts on body balance and obstruction avoidance [13-15]. If one cannot locate a possible obstruction because of a lower awareness level, a trip or a fall will be expected [16]. Obstructions with different heights, widths, or depths require locomotion patterns of jumping over, stepping down, and going around. These locomotion patterns are common when facing obstructions and are compulsory elements in successful locomotion. Locomotion patterns cause changes in gait patterns and demands for physical and conscious qualifications [17,18].

While walking, the visual system provides important information on the surroundings and contributes to route planning and maintaining body stability [19,20]. The availability of visual information on the location of an obstruction significantly affects how a pedestrian deals with the obstruction. Loss of visual information while approaching an obstruction increases the risk of incorrect foot placement by 50% [21].

Although research has been conducted on the risk of mobile phone use while walking, research on multi-tasking using mobile phones is inadequate. Therefore, this study was conducted to test the influence of multi-tasking on gait in different illumination settings.

Methods

Subjects

Twelve healthy adults from Sahmyook University in Seoul were included in the study. All participants were free of any medical conditions and used touchscreen smartphones. The study excluded candidates with abnormal limbs, a history of nerve disease, inability to use a touch screen, and less than six months of smartphone experience. The study was conducted after obtaining approval from the

ethics committee of Sahmyook University. Prior to participation, subjects received an explanation of the objective and methods of the study and completed a consent of agreement.

Procedures

The experiment was performed inside a flat lecture room in Sahmyook University. Testing conditions included: 1) Walking with an obstruction under a bright illumination level; 2) walking with an obstruction with a low level of illumination; 3) walking with an obstruction while texting under a bright illumination level; 4) walking with an obstruction while texting with a low level of illumination; 5) walking with an obstruction while gaming under a bright illumination level; and 6) walking with an obstruction while gaming with a low level of illumination. All participants were asked to text the Korean national anthem by their own phone and play Temple Run 2 (Imangi Studios, Raleigh, NC, USA) using an iPhone 5 (Apple Inc., Cupertino, CA, USA). Participants began texting and gaming just before they began walking. To minimize light adaptation, dark and light shades were applied correspondingly. Gait variance was measured for a length of 3 m, excluding the 1 m walked before and after the tested area. The experiment value was the mean value after three trials for each subject. To measure the data, a gait analyzing tool (OptoGait, 2010; Microgate Srl, Bolzano, Italy) was used. The analyzing tool contained two transmitters, a 1 m receptor stick, and a webcam (Logitech



Figure 1. Texting and gaming on gait while walking with an obstructions under different illumination levels.

Webcam Pro 9000; Logitech International S.A., Lausanne, Switzerland). OptoGait software (version 1.5.0.0; Microgate Srl) was used to analyze the gait data. The intra-class correlation coefficients for test-retest reliability of OptoGait were between 0.785 and 0.982 [22]. A table 75 cm in length, 30 cm in width, and 30 cm in height was used to create an obstruction (Figure 1).

Data analysis

Statistical software (IBM SPSS Statistics version 19.0; IBM Co., Armonk, NY, USA) was used for data analysis.

Table 1. General characteristics of subjects (N=12)

Characteristic	Value
Gender (male/female)	6/6
Age (y)	23.50 (4.89)
Height (cm)	167.42 (7.88)
Weight (kg)	63.92 (10.25)
Dominant hand (right/left)	11/1
Phone OS type (iOS/Android)	4/8
Duration using a mobile phone (y)	10.00 (2.45)
Time using a mobile phone per day (h)	3.17 (1.11)

Values are presented as number only or mean (SD).

The experiment used descriptive statistics for each participant's general features. All variables were compared among the different conditions using repeated two-way analysis of variance. A significance level of $p < 0.05$ was applied to all analyses.

Results

The general features of the 12 participants are shown in Table 1. The participants ranged in age from 20 to 36 years with a mean age of 23.5 years. They averaged 3.17 hours of smartphone use per day. Compared to the normal gait, gait speed, step length, stride length, step time, stride time, cadence while texting and gaming showed significant differences ($p < 0.05$) (Figure 2). Differences between contrasting illumination levels included gait speed, step length, stride length, and step time ($p < 0.05$) with no significant differences in stride time or cadence (Table 2).

Discussion

Multiple concurrent tasks often require attention during daily activities [6]. To adapt to the external environment,

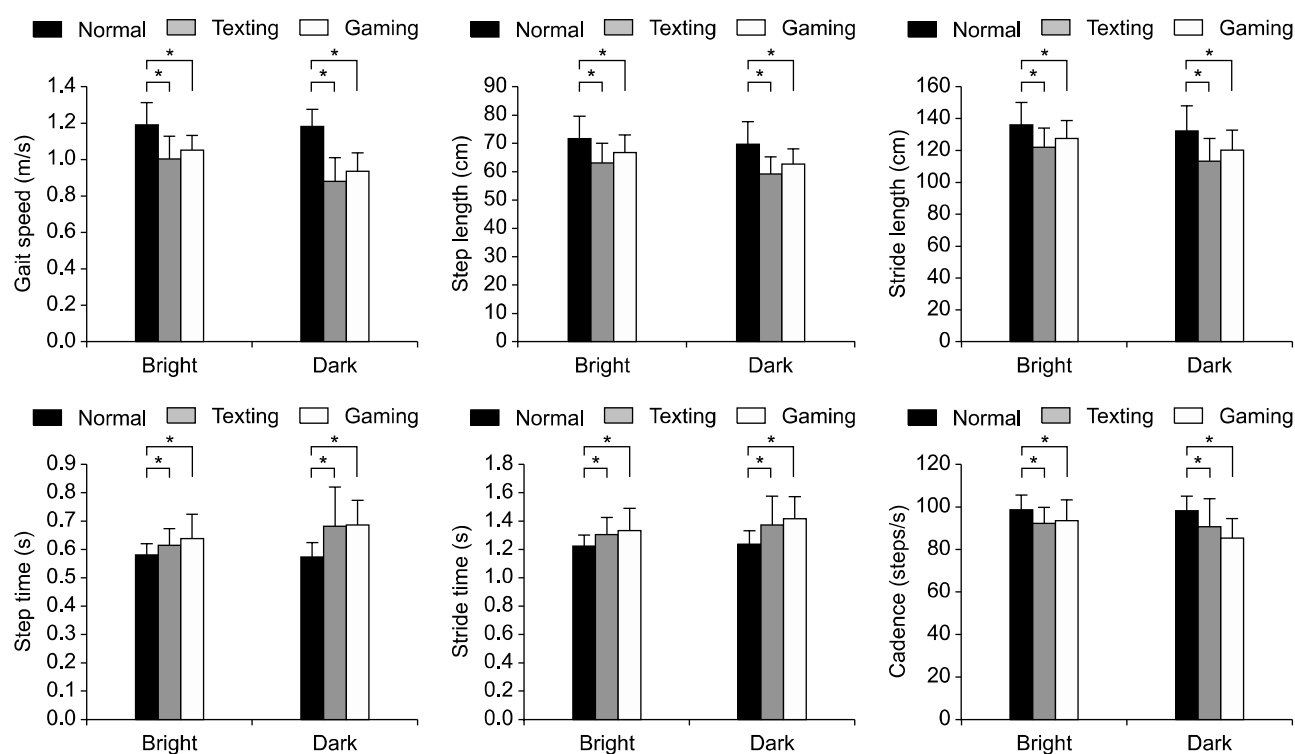


Figure 2. Differences of gait parameters in normal, texting, and gaming gait. *Significant differences between normal and texting, normal, and gaming ($p < 0.05$).

Table 2. Comparison of normal, texting, and gaming gait in different illumination levels

(N=12)

Parameter	Normal		Texting		Gaming	
	Bright	Dark	Bright	Dark	Bright	Dark
Speed (m/s)	1.19 (0.12)	1.18 (0.10)	1.00 (0.12)	0.88 (0.13)	1.05 (0.09)	0.94 (0.10) ^{a,b}
Step length (cm)	71.57 (8.07)	69.72 (7.77)	63.01 (6.80)	59.38 (5.77)	66.73 (6.21)	62.70 (5.64) ^{a,b}
Stride length (cm)	136.04 (13.97)	132.10 (15.72)	122.25 (11.57)	113.53 (13.86)	127.93 (11.25)	120.81 (12.36) ^{a,b}
Step time (s)	0.58 (0.04)	0.58 (0.04)	0.61 (0.05)	0.68 (0.13)	0.64 (0.08)	0.69 (0.09) ^{a,b}
Stride time (s)	1.23 (0.08)	1.24 (0.09)	1.31 (0.11)	1.37 (0.19)	1.33 (0.15)	1.42 (0.16) ^a
Cadence (step/s)	98.39 (6.71)	97.78 (7.07)	92.48 (7.35)	90.55 (13.05)	92.80 (10.42)	86.18 (8.43) ^a

Values are presented as mean (SD).

^aSignificant differences between normal and texting, normal, and gaming conditions ($p<0.05$). ^bSignificant differences between bright conditions and dark conditions ($p<0.05$).

proper posture with good body balance is necessary [23]. Multi-tasking can be defined as performing multiple tasks during the same period of time [24]. Previous multi-tasking research focused on hand motion while walking, verbal activity while walking [25], and simple reflection period time during the gait [26]. Multi-tasking causes a serious influence on gait in adults, slowing the locomotion and requiring a greater base of support [27,28]. This effect on gait occurs because the balance system increases in stability when faced with a threat [29,30]. Disturbances to stability can occur in a chaotic environment; however, executive function and attention are needed to sustain body safety and locomotion pattern [31]. Texting while walking results in negative dynamic stability because it combines a physical task and a cognitive action [31]. Obstructions and the visual system also have an impact on dynamic stability. People normally face obstructions and unorganized roads while walking. Nevertheless, these types of obstructions alter the locomotion pattern. Jumping over an obstruction increases the demand on the locomotion pattern and increases the chance for a fall [32]. The visual system not only provides information on obstructions but also maintains balance [20] and change of route [33]. Multi-tasking is influenced by the fear of falling. Fear of a fall decreases gait speed and step width which may change the locomotion pattern [34].

In this experiment, we studied how smartphone multi-tasking under different illumination levels influenced the gait with obstructions. Compared to gait under normal conditions, texting and gaming caused a significant decrease in gait speed, step length, stride length, and cadence ($p<0.05$) with an increase in step time and stride time ($p<0.05$). However, no significant difference was shown between the texting and gaming gait pattern. Sending an email or texting while walking requires focused attention. Gaze transfers or

gaze fixations while texting or writing an email alter locomotion patterns [34]. Demura and Uchiyama [35] supported our data by analyzing stride length and gait speed. Also, Lamberg and Muratori [12] reported in their recent experiment that multi-tasking results in cognitive distraction which slows gait speed and causes deviation from a straight path. Harbluk *et al.* [36] discuss how pedestrians have a slowed gait speed because of their fear of facing obstructions and fear of a fall. Moreover, distractions from multi-tasking exposes a person to more possible threats from the surroundings. Ebersbach *et al.* [37] reported that young adults from age 20 to 42 years have changed their locomotion pattern because of secondary tasks such as fine motor tasks and finger tapping. Our experiment also supported the idea that multi-tasking has a great impact on gait variables.

The experiment with different illumination levels shows that levels of illumination decreased gait speed, step length, and stride length ($p<0.05$) and increased step time ($p<0.05$). Interestingly, stride time increased in both illumination levels while cadence decreased. In a normal gait, visual sight takes a dominant role in body balancing and target change [38]. Visual information also determines gait route, step time, cadence, stride length, and stance phase [19,39-41]. Blurring, disturbing, or occluding sight decreases step length, which can result in foot placement error [33,42,43] and often changes the locomotion pattern and deviation [40]. A mock test with restricted sight decreased the step speed [44]. Previous studies reported that the reasons for decreased step speed are fear of a fall, fear of uncertainty, and fear of exploration. Those reasons can be defined as a conservative strategy [20,45]. Choi *et al.* [46] reported that under low light, gait speed and stance phase ratio of young adults decreased. Studies of elderly participants reported that gait speed and stride length decreased with obstructions.

Other studies report that they adopt the gait pattern as time increases [47,48]. Interestingly, when elderly people experience a decrease in their visual ability, they have more gait stability by slowing their gait, decreasing step length, and using more double-limb support [26,49]. Studies on young adults show that changes in illumination levels have a great impact on gait speed, step length, stride length, and step time. Visual perceptions of the surroundings can prevent encountering obstructions [20], but restricted visual perceptions may increase the chance of a fall [50].

Our study had some limitations. First, the obstruction was not rearranged between trials. It is possible that candidates were fully aware of the obstruction in all six conditions. Second, the experiment was carried out in a simple and quiet space. Third, we limited the participants to young adults. So there is a risk to generalization of all ages to use a smartphone. Further studies are expected on gait pattern changes with auditory, visual, and other sensory systems.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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