Does mixed reality influence texting while walking among younger and older adults?

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ABSTRACT

Young and older adults have difficulties in performance of an additional task while walking (dual task). This feasibility study investigates the dual task costs of texting on a mobile phone and walking among young and older adults, as well as the potential of a mixed reality app, which projects the real world onto the background of the mobile display, to modify these costs. Seven young (age 26.4±4.5 years) and 7 older (age 69.9±3.9 years) adults were asked to walk while texting on a custom-written mobile android app (with and without mixed reality display), as well as to perform each task (walking, texting) separately. Preliminary results show that dual task interference of both tasks is similar in both groups. Using a mixed reality display does not modify these costs, but does affect the subjective experience of the groups differently. This may be due to different levels of familiarity with mobile phone use in the two groups. Additional data is currently being collected.

1. INTRODUCTION

Functional locomotion involves performance of multiple (two or more) concurrent tasks, i.e. dual tasking. Additional cognitive load changes locomotion patterns in healthy and, particularly in older adults or clinical populations (Yogev-Seligmann, Hausdorff, & Giladi, 2008). For example, healthy young adults decrease gait speed while performing another task (Abernethy, Hanna, & Plooy, 2002), especially when talking (Plummer-D'Amato, Altmann, & Reilly, 2011).

Due to advances in technology, people increasingly perform a novel type of dual task during walking – using a smartphone. Indeed, these devices have become an inseparable part of our daily life; we use smartphones to text, take pictures or browse the web while performing other activities of daily life, notably walking. For example, pedestrians who talk on the phone exhibit more unsafe behaviors, potentially endangering themselves and others when crossing roads (Nasar, Hecht, & Wener, 2008; Neider, McCarley, Crowell, Kaczmarski, & Kramer, 2010). Texting while walking, in comparison to talking while walking, generates stronger interference with gait (Lopresti-Goodman, Rivera, & Dressel, 2012) due to the added visuo-motor distraction. However, research on the effect of texting on walking began only recently. Indeed, young adults who text while walking experience changes in gait including a slower pace and altered spatio-temporal stability of the center of mass, specifically in the frontal plane (Kim, Park, Cha, & Song, 2014; Lamberg & Muratori, 2012; Lim, Amado, Sheehan, & Van Emmerik, 2015; Marone, Patel, Hurt, & Grabiner, 2014; Plummer, Apple, Dowd, & Keith, 2015). Only one study evaluated performance of older adults while using a smartphone concurrently with walking (Takeuchi, Mori, Suzukamo, Tanaka, & Izumi, 2016). However, this study did not measure gait speed and did not use a texting task but rather a game played on the mobile phone.

A possible solution to the problem of distraction during use of a mobile device involves the addition of information from the smartphone user's surroundings onto the mobile phone display. This solution may enable the user to continue to look at the phone with increased awareness of the environment. This is an example of "Mixed Reality" (MR), a location along Milgram & Kishino's (1994) reality-virtuality continuum which involves the merging of real and virtual worlds. Products such as Google Glass and Microsoft's Hololens are leading examples in this evolving field, enabling users to remain present in their environment while interacting with a mobile device. For example, a simple solution for writing text while walking is to use the mobile device's camera to display the actual field of view while still being able to use the keyboard; the real world is projected onto the smartphone screen as shown in Figure 1.

Figure 1. *An example of an off-the-shelf application (Type n walk, www.type-n-walk.com) projecting the real world view captured by the smartphone camera behind a data layer (e.g., used for writing text).*

Although such a solution has considerable potential for decreasing texting-related pedestrian accidents, its effect on walking is largely unknown. Furthermore, the effect of texting with or without the use of MR technology may vary between young and older adults, and may pose an additional barrier to learning in older adults, further impairing their performance. Older adults tend to be slower, more variable and less accurate in their performance of fine motor skills (Welford, 1962), as well as in their ability to learn novel fine motor tasks such as precision grip, computer typing, and different finger and arm movements (Voelcker-Rehage, 2008). The performance decline in fine motor skills in older adults has been explained by a multitude of factors such as decreased visual and auditory perception, psychomotor speed, visuo-motor coordination and executive control (Birren, 2013; Krampe, 2002). When presented with a task such as mixed-reality texting performed concurrently with a gross motor task (walking), older adults may not achieve the required performance level needed to engage with the real world (e.g., walk fast enough to cross a road). Given the pervasiveness of mobile technology, it is important to evaluate the ability of older adults to use mobile devices concurrently with performing daily tasks such as walking.

The overall objective of this study is to evaluate the effect of texting with and without MR on walking in real life situations. Specifically, the objectives of this paper are:

1. To compare the effects of texting while walking on walking and texting speed in young and older adults.
2. To evaluate the subjective and objective effects of using mixed reality while texting and walking in young and older adults.

2. METHODS

2.1 Participants

Participants were recruited for the study in two groups according to age; 20-45 years and >65 years. In order to participate, they were required to own and use a smartphone for writing text messages (among other uses) for >1 year and, in the case of the older adults, were required to score > 19 on the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) to exclude moderate cognitive impairment. Participants were excluded if they had orthopedic or neurological impairment affecting locomotion, any pain during walking, or an uncorrected visual or hearing impairment, used an assistive device to walk (cane, walker, etc.) or reported an inability to text or read while walking (e.g., due to dizziness).

2.2 Experimental tasks and apparatus

2.2.1 Experimental apparatus

- *Mixed Reality texting application*. A custom-written Android application was used, enabling the participants to input text on screen while being presented with the primary camera's live stream in the background. The application was developed in order to enable standardization of the texting task across participants, i.e. use the same phone, keyboard and avoid incoming private text messages or other pop-up messages during the experiment, in addition to providing complete information regarding texting performance (deletions, speed, etc.). The Android app was run on a Samsung Galaxy S4 smartphone, running Android 4.2.2 (JellyBean). Dimensions of the phone were 136.6 x 69.8 x 7.9 mm, 5.0″ screen, and mass 130 g. The phone was equipped with a 13MP, 4128x3096 pixel camera. Text to be typed by the participant was presented on the upper part of the screen and the user's input was displayed below it (Figure 2). In the background, it was possible to display the camera's input stream such that the field of view was not obstructed by the phone. In conditions where MR was not used, the background was left black. The app logged typing output (timing of every character typed) which was written to a text file and exported via e-mail for offline processing.

- *Mobility Lab sensor system.* Walking kinematics were recorded with a commercial sensor system (Mobility Lab, APDM Inc., Portland, OR) using 3 OPAL sensors (48.5 x 36.5 x 13.5 mm, 22 grams each) mounted on the participant's shanks (2 sensors) and on the lumbar spine (one sensor; Figure 2, right panel). Mobility lab sensors provide 6 degrees of freedom data (three-dimensional acceleration and three-dimensional gyroscopic data) recorded at 128 Hz. Mobility Lab sensors have been used to detect gait and balance performance in healthy individuals as well as in people with neurological conditions (Baston, Mancini, Schoneburg, Horak, & Rocchi, 2014; Weiss et al., 2015).
- *GoPro camera.* Navigation in the environment was documented using a GoPro Hero2 camera affixed to the participant's sternum (Figure 2, right panel). The camera's wide field of view (127-170 degrees) enabled documentation of events during testing (e.g., people crossing the path, sounds).

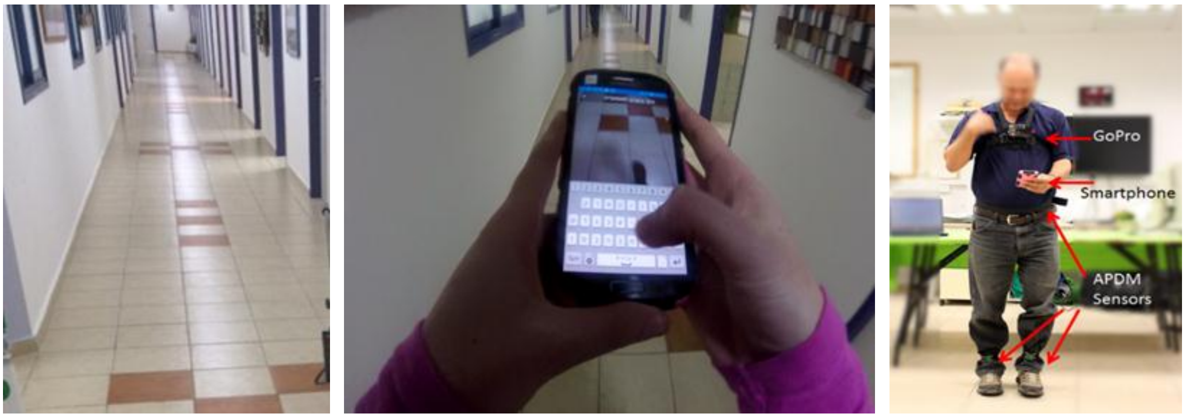

Figure 2. *Left panel: setting of walking conditions, a quiet, well-lit university corridor. Center panel: the MR app main screen. During the mixed reality condition, the back camera view is projected behind the text (view shown in this figure). In other conditions, the background is blackened. Right panel: experimental setup. Three APDM sensors are attached to the ankles and at the hips. A GoPro camera is attached to the chest, pointing forward.*

2.2.2 Additional assessments

- *Trail Making Test (TMT*) is a test that assesses visuo-motor scanning, divided attention and cognitive flexibility. Individuals are requested to draw a line to connect a series of characters that alternate between numbers and letters (i.e., 1-A-2-B-3-C, etc.). Time to complete the task is measured. This is a widely used test that was found to be predictive of falls among older adults (Reitan & Wolfson, 1995; Tombaugh, 2004).
- *Montreal Cognitive Assessment (MOCA)* is a screening test that was developed to detect mild cognitive impairment. The test screens cognitive abilities in seven domains (e.g., executive functions and memory) with scores ranging from 0 to 30. The test was found to be reliable and sensitive to detect mild cognitive impairment (Nasreddine et al., 2005).
- *Timed-Up-and-Go (TUG) and TUG-cognitive.* The TUG measures the time taken by a participant to stand up from a standard chair, walk 3 meters, turn, walk back and sit down in the chair (Shumway-Cook, Brauer, & Woollacott, 2000). This test was found to be valid and reliable for predicting falls among older adults (Schoene et al., 2013). Participants in the study completed the TUG as well as the TUG-cognitive, where a subtraction (by 7) task was performed concurrently.
- *Motor tapping.* Maximum typing speed was assessed by asking participants to continuously type a single character (space) as fast as they could on the mobile phone in the absence of additional visual input.

2.3 Procedure

Participants were tested during a single one-hour session. After signing informed consent forms, participants were asked to complete a demographic questionnaire including details about their mobile phone usage. Then, they performed the TMT, TUG and TUG-Cognitive, and the older adults also completed the MoCA. The experiment took place in a quiet, well-lit indoor university corridor (Figure 2, left panel). This corridor was selected since its lighting distribution minimized glare and reflections. Participants were asked to walk along a 30-meter path for one minute, in one of three conditions: walking while holding the phone in their hand (Single Task (ST)), walking while texting (Dual Task (DT)), and walking while texting with MR (i.e., with the camera view in the background (MR)). Additionally, participants were asked to text for 1 minute while standing still. The order of the four conditions for each participant was selected using block randomization. During the texting tasks participants were required to copy simple 3-word sentences in Hebrew (their native language), similar to text messages, presented on the top part of the screen (e.g., "I wore a sweater to work"). Order of the sentences was randomized, and different sets were used for every walk condition to avoid memorization. Autocorrect was turned off. Finally, maximum typing speed was measured by typing a single character on the mobile phone (motor tapping).

Following testing, two visual analog scales (VAS), 10 cm black lines anchored by two end points on a white card, were presented to the participants asking them to cross the line to show how much they used visual input via the smartphone screen while walking (VAS 1: "How helpful was the background screen presentation (when presented)?" not at all→very helpful), and whether they would use such an app in real life (VAS 2: "How likely are you to use such an app in the future?" not likely at all→very likely).

2.4 Outcome measures and data analysis

Data analysis was performed using custom-written Matlab code (Matlab R2015, Natick, MA). Data from motion sensors on shanks and hips was filtered using a second order Butterworth filter (dual-pass, 70 Hz low-pass) and gait events (heel strike, toe-off) and turns were identified according to the method described by Simoes et al. (2011); Timing of heel strike was identified from peaks in vertical acceleration signals of the shank sensors. Stride time was calculated as the temporal difference between consecutive peaks in the same leg. Stride length was calculated using data from gyroscopes in the shank sensors. Angles of the shank in the sagittal plane were identified from gyroscopic data of the shank sensor at the moment of heel strike (separately for the right and left leg heel strike). According to the law of cosines, the joint angle ($\alpha + \beta = \gamma$) relates to leg length (l) and step length (s) in the following way:

$$s = l * \sqrt{2 - 2cos\gamma} \tag{1}$$

The same procedure was performed for two consecutive steps, and step lengths were summed to obtain stride length. Although limited by not taking the knee angle into account, this method has been used with wearable sensors in both healthy and clinical populations and results in excellent correlation coefficients when compared to gold-standard motion capture systems (Horak, King, & Mancini, 2015; Mariani et al., 2010). Stride length and time were used to calculate gait speed. Finally, covariance of gait speed, stride length and stride time were calculated for each subject in every condition.

Data of texting performance was extracted from Excel files produced by the mobile app. Texting speed (measured in Characters Per Minute, CPM) was calculated by dividing the time required to write each sentence by the number of characters typed including spaces. This value was averaged across all sentences typed within a single condition. Similarly, the maximum tapping speed was calculated for the typing speed condition. Texting accuracy was measured using the Levenshtein distance, a metric evaluating the minimum number of single-character edits (i.e., insertions, deletions or substitutions) required to change one string of characters into another (Levenshtein, 1966). The final typed sentence was compared to the displayed sentence, and the mean Levenshtein distance for all sentences in a specific condition was calculated. The number of deletions performed to obtain the final text was calculated separately, as deletions during text writing are usually undetected when only final strings are available, but may also influence accuracy and speed of text writing.

Dual task cost (DTC) of gait speed, stride length and stride time, as well as texting speed were calculated using the following formula (Plummer & Eskes, 2015):

$$DTC(\%) = 100 \cdot \frac{Single\ task\ performance - Dual\ task\ performance}{Single\ task\ performance} \tag{2}$$

Subjective user experience for using the MR app was evaluated by calculating the position of responses on the visual analog scales, dividing by total length of line and multiplying by 100.

Due to the small sample size, non-parametric tests were used to compare gait parameters (mean gait speed and DTC) and texting (mean typing speed and DTC) for between group (Mann-Whitney) and within group (Wilcoxon) comparisons across the various conditions: single task (ST), dual task (DT) and dual task with mixed reality (MR). It should be noted that data for cycle time covariance for one older subject was removed following outlier analysis.

3. RESULTS

3.1 Feasibility of protocol

To date, seven young and seven older adults completed the study protocol. None of the participants reported difficulties with the protocol and all were able to complete all conditions. In addition, no adverse events were observed.

3.2 Participants characteristics

Participant characteristics are described in Table 1 below. Older adults have less experience in texting compared to younger adults as most of them (71.4%) reported that they text less than 10 times a day as opposed to the younger group where only 28.6% reported texting in low frequency. In addition, older adults reported that they rarely tend to text while walking. No significant between-group differences were found in TUG, TMT-B and maximum finger tapping speed.

3.3 Between group comparisons

Gait and texting parameters across conditions, of both groups, are presented in Table 1 and figures 3-5. The younger group typed significantly faster than the older group during the three experimental conditions (ST; U=5.0, p=.01; DT; U=6.0, p=.02; MR; U=4.0, p=.009). No significant group differences were found in gait speed during all conditions and in DTCs of gait speed and typing speed.

3.4 Within group comparisons

As compared to ST, both groups walked significantly slower during the DT (younger; z=-2.4, p=.02; older; z= -2.2, p=.03) and MR (younger; z=-2.2, p=.03; older; z= -2.4, p=.02) conditions. There were no significant differences in gait speed between DT and MR conditions for either group.

As compared to ST, both groups typed significantly slower during the DT condition (younger; z=-2.4, p=.02; older; z= -2.4, p=.02). As compared to ST, only the younger group typed significantly slower during the MR condition (z=-2.2, p=.03). There were no significant differences in typing speed between the DT and MR conditions for either group. In addition, there were no significant differences between DTCs of gait speed nor in DTCs of typing speed for either group.

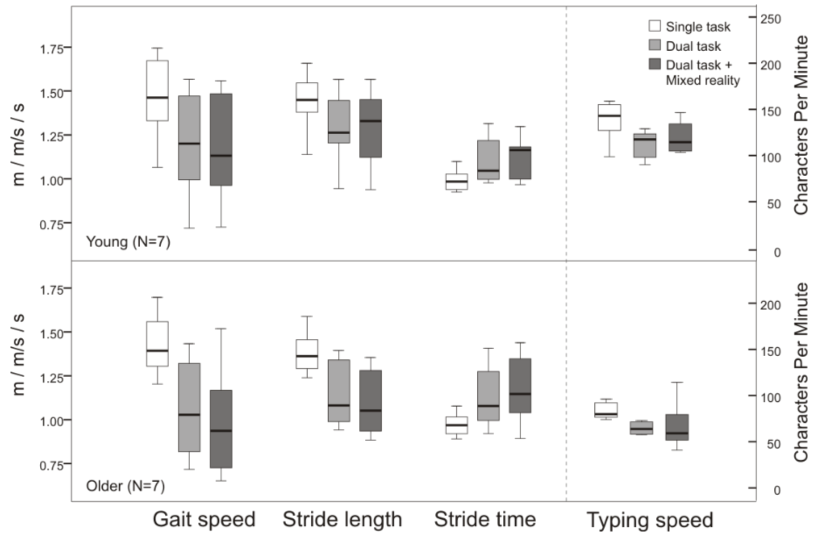

Figure 3. *Gait spatiotemporal parameters and text typing speed for young (top panel) and older adults under three conditions: Single task (walking/texting only), dual task (walking and texting) and dual task with mixed reality (walking and texting with mixed reality display).*

Table 1. *Participants' characteristics and performance on clinical tests.*

	Young (N=7)	**Older (N=7)**
Gender	4F/3M	4F/3M
Age (Years)	26.4±4.5	69.9±3.9
Height (cm)	164.4±8.2	164.4±9.0
Dominance (Left/Right hand)	2L/5R	2L/5R
Current phone's operating system	7 Android	6 Android / I iOS
Time with current phone (months)	16.0±15.7	6.6±3.5
Texts per day (% of subjects)		
Under 10	28.6	71.4
10-30	28.6	28.6
31-50	28.6	
51-70	14.3	
Use phone while walking (% of subjects)		
Not at all	14.3	42.9
>25% of walk time	42.9	57.1
25%-50% of walk time	14.3	
50%-75% of walk time	14.3	
>75% of walk time	14.3	
Ever stumbled/fell while using phone		
No	71.4	100
Yes	28.6	-
If yes, how often		
Rarely	-	-
Occasionally	100	-
Often	-	-
TUG	6.57±1.03	7.43±0.76
TUG-cognitive	7.37±1.60	7.42±0.77
MoCA	--	24.14±3.02
TMTa	27.95±6.03	38.41±10.83
TMTb	72.82±22.38	82.94±37.35
Maximum typing speed	295.13±6.16	299.47±5.48

3.5 Subjective experience

Young adults found the mixed reality presentation to be moderately helpful with a VAS 1 median score of 28.32 (IQR=19.47-84.07). Older adults, however, reported that they did not find the mixed reality helpful with a VAS 1 median score of 4.42 (IQR=0.0-13.27). The difference between the groups was significant (U=3, p=.006).

With regard to the likelihood of using an MR app in the future, the older adults reported a median VAS 2 score of 7.96 (IQR=0.0-11.50) while the young adults reported a median VAS 2 score of 27.43 (IQR=9.73-71.68). The difference between the groups was significant (U=8, p=.04).

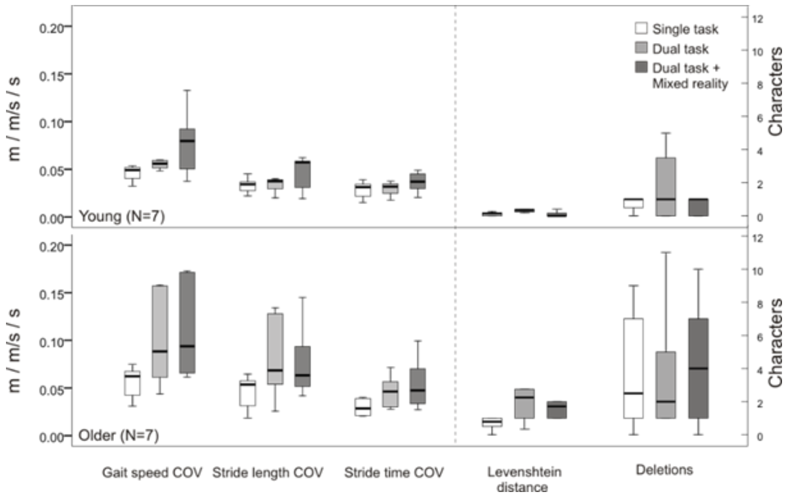

Figure 4. *Covariance of gait spatiotemporal parameters (left) and additional texting parameters (accuracy-Levenshtein distance and number of deletions) for young (top panel) and older adults under three conditions: Single task (walking/texting only), dual task (walking and texting) and dual task with mixed reality (walking and texting with mixed reality display).*

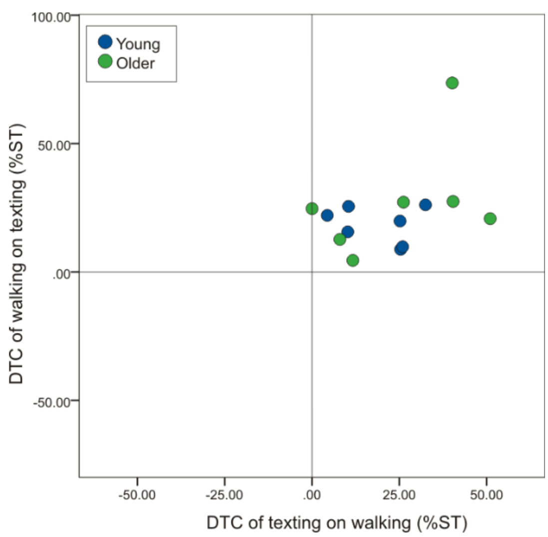

Figure 5. *Dual Task Cost (DTC) of texting on walking (gait speed) vs. DTC of walking on texting (typing speed) for young (green) and older (blue)subjects. Positive values of DTCs indicate a dual-task interference effect.*

4. CONCLUSIONS

These initial results showed that texting while walking generated similar patterns of decrements in the performance of walking while texting tasks in both young and older adults. According to Plummer and Eskes (2015), a complete measurement of dual task interference needs to include the cost of each task on the performance of the other. In the current study, no facilitation of either task was noted for either young or older adults, nor did there appear to be a trade-off between the two tasks. Rather, dual task performance resulted in interference for both texting and walking (Figure 5). These findings extend the results from existing studies, which only described decrements in gait performance while texting in young adults (Lim et al., 2015; Lopresti-Goodman et al., 2012; Parr, Hass, & Tillman, 2014; Plummer et al., 2015; Schwebel et al., 2012).

Differences between the groups in all conditions were found only in the texting task. This may be due to the familiarity and experience of the younger adults with texting with and without walking, as was indicated by their self-reports. A larger sample of older adults may permit discrimination between different levels of familiarity with the task in this population as well. The lack of differences between the groups in the other parameters as well as in the DTC may be explained by the relatively quiet walking environment that did not impose challenges to the high-functioning (community dwelling) older adults who participated in this study. In addition, the small sample size may have prevented some of the differences from reaching statistical significance.

The initial findings reported in the current paper support the feasibility of the protocol for studying the dual-task cost of texting while walking, and especially the contribution of MR to the ability to perform this type of dual-task. The similar patterns of performance that were observed in older and younger adults (e.g. lack of differences in gait and typing speed between the DT and MR conditions within both groups) further support the feasibility of the protocol. From these initial results it seems that MR did not affect performance of texting while walking. However, younger adults reported that it was more helpful to them and that they will be more likely to use it in the future. This may reflect generational differences in adopting new technologies during routine daily activities, and may have implications for the design of mobile phone applications for older adults in the future, e.g. larger texts or higher contrast to accommodate older users (Holzinger, Searle, & Nischelwitzer, 2007). The ability of older adults to modify performance under these dual-task conditions over time should also be investigated using a motor learning paradigm.

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