Original Research

Changes in Gait and Texting Ability During Progressively Difficult Gait Tasks

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ABSTRACT

International Journal of Exercise Science 10(5): 743-753, 2017. To investigate the effects of a cell phone texting task on an individual's ability to perform three ambulation-based tasks, each with different and progressively more difficult demands. 36 participants (24 male/12 female, average age 23.4) performed: a Timed Up & Go (TUG), stair ambulation (STAIR), and tandem gait (TAN). Participants completed each gait-based task under four conditions: as a practice, while holding their cellular device (baseline), while texting a message, and while reading a message. Statistically significant differences were found within the following variables: 1) mean time to complete a gait task increased through the conditions (Baseline, Texting, Reading), 2) mean number of gait deviations increased while texting during TAN condition in comparison to baseline, 3) mean characters per second became less only in the STAIR task, 4) mean number of texting errors per second increased only in the TAN task. The reduction of gait speed, from baseline to texting, were similar to each other (average 2.46 sec) despite the difficulty of the task (TUG, STAIR, TAN). Results of this study reaffirm that texting while walking produces slower gait. However, the degree that gait slows does not appear proportional to the level of difficulty of gait task. Comparatively, more challenging gait tasks resulted in increases in both path deviations, texting errors and decreases texting speed. These findings suggest that increased dual-task demands result in decreased efficiency in both texting and walking performance.

KEY WORDS: Gait, texting, dual task, gait speed, texting errors

INTRODUCTION

The incidence of pedestrian accidents related to mobile devices has been on the increase in the United States. A nearly three-fold increase in pedestrian/mobile device incidences occurred between 2004 and 2010 (11). A study in an urban area revealed that one in three pedestrians used their cellular devices while crossing a street. Additionally the study showed they walked 18% slower and were significantly more likely to walk outside the designated crosswalk area (17). A study by Schwebel et al. showed that distracted walkers were more likely to be "hit" in a virtual crosswalk (15). Nasar and Troyer state that most pedestrian texting injuries occur to

those under the age of 31 and that most injuries are a result of distraction leading to unsafe street crossing, falling off curbs and walkways and bumping into objects. Some of the types of ensuing injuries were concussions, fractures, contusions, dislocation, abrasion and sprains and strains (11).

As the prevalence of injury related to walking and mobile devices increased, more research needs to be done regarding the nature of distracted walking. Most research performed in the area of distracted walking is based on a dual-task paradigm, which assumes a limitation in one's information-processing capacity. Therefore when two tasks are performed simultaneously the information processing capacity of each task surpasses the total capacity leading to a deterioration of one or both tasks (16). The effect of cognitive tasks on gait has been significantly researched. Both older and younger adults show a deterioration of gait speed and gait stability when given a cognitive task with older adults showing a greater deterioration (4, 5). Dubost et al. found that rhythmicity of gait, not just velocity, is disrupted in dual task conditions indicating that some attention is given to the control of rhythmic stepping (3). Researchers have looked into not only the effect of the cognitive task on gait, but the demand of the gait task. Kelly et al. showed a shift in prioritization from the cognitive task to the walking task as the task became more difficult (6). Research performed by Mersmann et al. evaluated how young and old adults prioritize dynamic stability control when performing a concurrent cognitive task and then presented with a perturbation. The dual task condition that was presented to the subjects did not affect ability for them to recover from a sudden perturbation thus indicating a prioritization of gait when there is perceived threat to stability (10). Current research that focused specifically on texting while walking has had similar findings as prior gait and dual task studies. Schabrun et al. focused primarily on the effects of reading and writing text messages on gait, finding texting individuals walk slower, and with increased lateral variance. Additionally, the researchers found decreased neck and head movement while texting and walking, presumably to improve one's ability to read or write a message (14). Other studies have found gait to be slower (1,7,8,12,18) and have found gait deviations (1,7). In continuous straight line walking Plumber et al. specifically found that young adults do not significantly modify texting in highly distracting environments (12). Similarly Strubhar et al. found little modification in texting ability when walking in a straight line (18).

Recent research has indicated that texting does interfere with gait speed and the ability to ambulate in a straight line suggesting there is limited capacity to doing two tasks simultaneously. To further explore this limited capacity while performing gait and texting this research introduced more difficult gait tasks. The added tasks (stairs and narrow walking) have not been studied before, yet could be performed by those that may text and walk at the same time. The researchers hypothesized that texting would have a more profound effect on gait speed and path deviation with more difficult gait tasks. Additionally the study explored the impact of reading versus texting on the gait tasks. Reading versus texting explores a difference that may occur with actual texting, which involves a fine motor, visual and expressive language component, versus a visual and receptive language component. It was hypothesized that reading a message would effect gait but to a lesser degree than texting.

Since only a very limited amount of research has looked at how gait might affect texting ability it was hypothesized that with more difficult gait tasks there would be a deterioration in texting ability as measured by texting speed and texting errors. This study is unique in that it uses a standard text message rather than a free form message. Knowing further the nature of the interference of texting on gait and any subsequent impairments of gait might inform policy makers and health care professionals regarding the safety or prohibition of doing these task together. Because texting is becoming a ubiquitous activity, texting could be a real world task that is added in the treatment of individual who have cognitive, balance and or gait impairments.

METHODS

Participants
Thirty-six healthy participants 18-30 years old were recruited (24 males, 12 females, average age of 23.4±2.3). Individuals were excluded for any limitations in gait, current health issues (such as diabetes, heart or lung problems), orthopedic or neurological impairments or recent surgeries. The participants reported familiarity with the text messaging system and each provided their own cell phone capable of sending and receiving text messages. The participants were also asked if they were able to turn off the autocomplete function on their phone. The participants were fully informed of the methods regarding their participation and provided written informed consent. The study was approved by Bradley University's Committee on the Use of Human Subjects in Research (Bradley University's Institutional Review Board).

Protocol
Following completion of an informed consent each participant was instructed through a baseline (BASELINE) texting protocol. The participant was requested to maintain a standing position while composing the provided text message of: "The black cow jumps over the metal fence and eats the green grass.", which was provided verbally to the participant prior to beginning the baseline measure. Each participant was informed that time and errors would be analyzed during this task and all other texting tasks that followed. They were not told to text as fast as they can. The time to complete the text was measured with a hand held stopwatch and was recorded. The text was sent to the researcher for analysis. Following completion of baseline texting measures the subjects were instructed through the remaining gait based tasks. This and all subsequent timed tasks were measured by the same researcher and with the same stopwatch.

The first gait-based task completed was a Timed Up & Go (TUG). This involved rising from a seated position, walking 3 meters, turning around, walking 3 meters, and returning to a seated position. The participant was seated on an 18-inch wooden chair with no arms. Time was started as soon as the participant lifted themselves from the chair and time was stopped as soon as they made contact with the chair after completing the task. The TUG task has excellent inter and intra-rater reliability (2). The subsequent tasks (STAIR and TAN) are variants of the TUG task.

The second task (STAIR) entailed rising from a seated position, as above, walking 3 meters, ascending 4 stairs, turning around, descending 4 stairs, walking 3 meters, and returning to a seated position. The stairs used were a 4-step, 7-inch rise standard practice stairs with a platform at the top for turning. Gait deviations from a straight path in both the TUG and STAIR task were counted when the participant step on or over two parallel lines set 40cm apart. This width provided a significant deviation that would approach an individual stepping off a sidewalk, drifting into the path of another ambulator, or striking a stationary object.

The third task entailed rising from a seated position, walking in tandem (TAN) heel to toe 3 meters on a 2"x4" wooden board, turning around, walking in tandem 3 meters on a wooden 2"x4" board, and returning to a seated position. The board was placed on a level and even surface with the wide dimension to the ground. Path deviations were counted if the individual stepped off the board. For all the gait tasks the participant was told that the number of deviations would be counted. They were not told to walk as fast as they could but rather told to walk at a comfortable pace. The gait tasks were not randomized in order to reflect a more real world encounter of texting while walking with first an unobstructed environment followed by an environmental challenge, i.e. stairs or need to narrow the base of support. The participant was allowed one initial trial in each task (TUG, STAIR, TAN) before the measurements were taken.

Each task entailed three ambulation-based conditions. The first condition required completing the gait-based task (TUG, STAIR, or TAN) while holding their preferred cellular device, with two hands, without composing or reading a text message (BASE). The second condition required completing the gait-based task while composing a provided text message (TEXT). This provided message was a variant of: "The black cow jumps over the metal fence and eats the green grass", in which the color of the cow, fence, and/or grass would be alternated to avoid learning bias related to the texting activity. The text message variant was composed so that the number of characters in the message was consistent between trials. In the third condition the participant was sent a lengthy text (544 words) and completed the ambulation task while reading the text (READ). Analyses of texting errors and characters typed per second were completed by the researchers reviewing the messages sent during testing.

Statistical Analysis
SPSS version 16.0 (SPSS Inc., Chicago, IL) was used to perform the statistical analyses. Significance levels were set at $p < 0.05$. Repeated measures ANOVA was used to determine if there was significant difference among the mean time and number of deviations of the three gait conditions (baseline, reading and texting) for each task (TUG, STAIR, TAN). Partial eta squared (η^2_p) was calculated to determine effect size. Paired t-tests with a Bonferroni adjustment were performed as a post hoc analysis and Cohen's *d* was calculated to determine effect size among significant pairs. Repeated measures ANOVA was used to determine if there was a significant mean time difference from the baseline to texting gait among the three tasks (TUG, STAIR, TAN). Partial eta squared (η^2_p) was calculated to determine effect size. Paired t-tests with a Bonferroni adjustment were performed as a post hoc analysis. Cohen's *d* was calculated to determine effect size among significant pairs. Repeated measures ANOVA as

used to determine if there was a difference in the texting characters per second and errors per second among the baseline text, TUG, STAIR and TAN texting tasks. Partial eta squared (η^2_p) was calculated to determine effect size. Paired t-tests with a Bonferroni adjustment were performed a post hoc analysis. Cohen's *d* was calculated to determine effect size among significant pairs.

RESULTS

Among this group of young adults (N = 36) there was a statistically significant difference between the conditions (Baseline, Reading, Texting) in the time to complete each gait task (TUG, STAIR, TAN). See Figure 1. ANOVA revealed a main effect for the TUG task $F_{(2, 70)}$ = 56.3. p = 0.001, η^2_p = 0.62, ANOVA revealed a main effect for the STAIR task $F_{(2, 70)}$ = 64.9, p = 0.001, η^2_p = 0.65. ANOVA revealed a main effect for the TAN task $F_{(2, 70)}$ = 25.0, p = 0.01, η^2_p = 0.42. See Table 1 for the post-hoc t-test results.
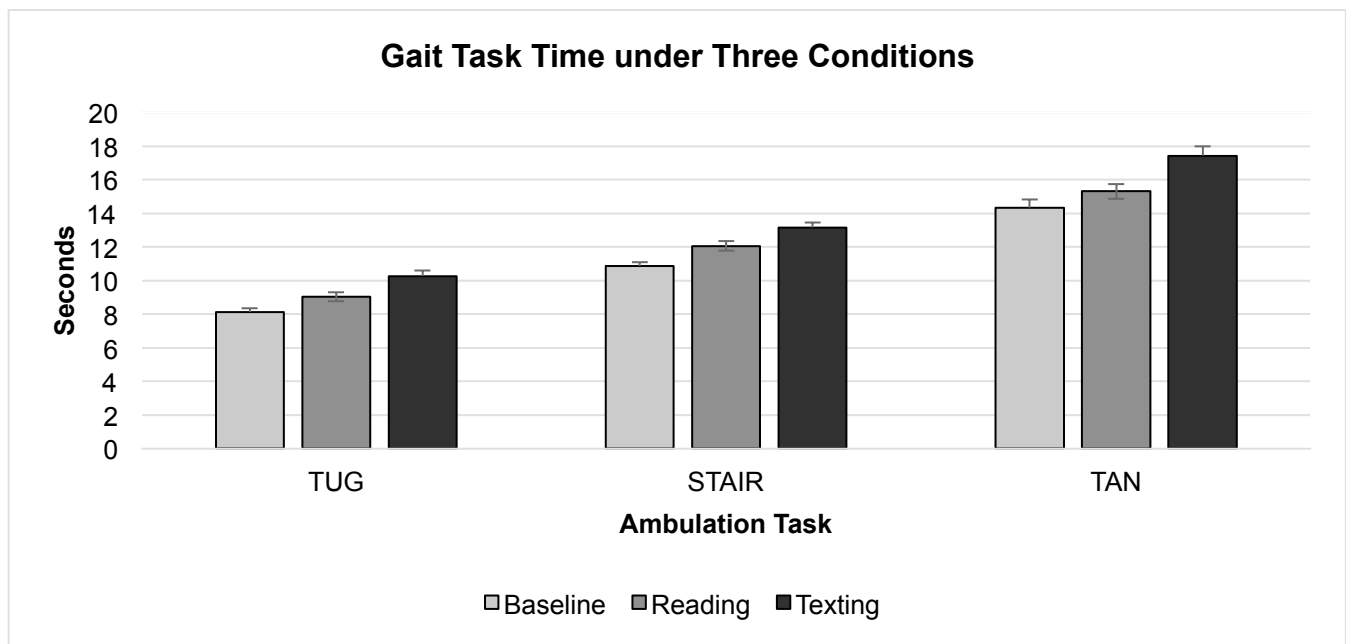
Figure 1. Mean time taken to complete three gait tasks: TUG (timed-up and go), STAIR (timed-up and go with stairs), TAN (timed-up and go with tandem walking) under three conditions: Baseline walking, walking while reading and walking while texting. Error lines are standard error. Significant main effects were found in TUG, STAIR and TAN.

For each task the texting added an average of 2.5 seconds or 17% longer. Reading added an average 1.0 seconds or 8% longer, but with only a moderate effect size.

The difference between the mean time during the baseline and during texting conditions were calculated (Table 2) to see if texting has a greater impact on gait time as the gait task got more difficult. The ANOVA revealed no main effect difference between these values, $F_{(2, 70)}$ = 2.80,

p =.068, η^2_p = .074, thus indicating that as the gait task progressed in difficulty, the texting did not interfere in any greater degree in time to complete the task.

Table 1. Post-hoc t-test (Bonferroni adjustment) results for gait task time under three conditions.

TASK	PAIR	t(35)	p	d
TUG	BASE:TEXT	-9.68	.001	1.61
	BASE:READ	-6.67	.001	1.11
	TEXT:READ	4.47	.001	0.74
STAIR	BASE:TEXT	8.91	.001	1.49
	BASE:READ	6.86	.001	1.14
	TEXT:READ	6.95	.001	1.16
TAN	BASE:TEXT	-5.95	.001	0.99
	BASE:READ	-2.35	.047	0.42
	TEXT:READ	5.0	.001	0.83

Table 2. Mean BASE to TEXT change among tasks

| TASK	Difference between BASE & TEXT	Difference between BASE & TEXT
	Time (sec.)	# of Dev.
TUG	2.10±1.3	0.20±.58
STAIR	2.28±1.5	0.14±.54
TAN	3.00±3.0	0.72±1.2
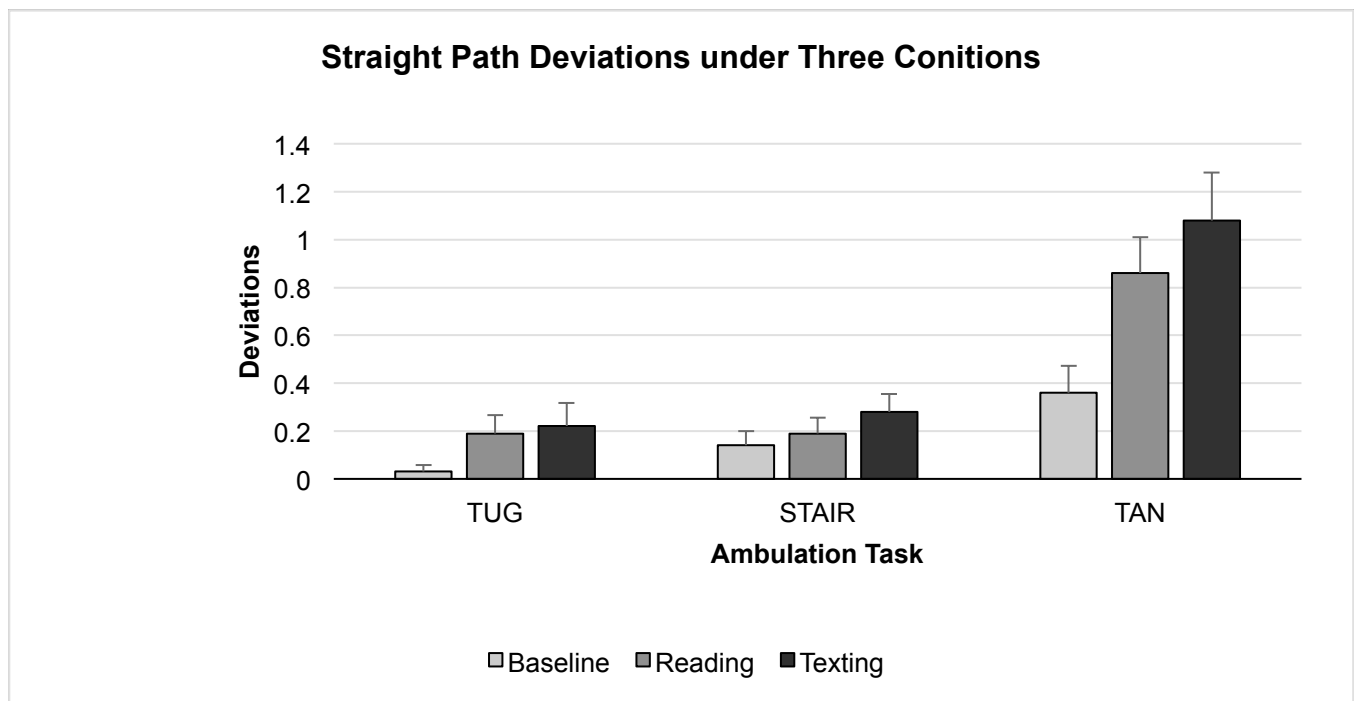
Figure 2. Mean number of straight path deviations in three gait tasks: TUG (timed-up and go), STAIR (timed-up and go with stairs), TAN (timed-up and go with tandem walking) under three conditions: Baseline walking, walking while reading and walking while texting. Error lines are standard error. A significant main effect of TAN was found.

Among this group of young adults there was not a statistically significant difference in the mean number of path deviation from the straight path between the conditions for the TUG task $F(2,70) = 3.0$, p = 0.06, η^2_p = 0.08, and for the STAIR task F $(2,70)$ = 1.1, p = 0.33, η^2_p =0.03. See Figure 2. The ANOVA did reveal a statistically significant main effect for TAN task F $(2,70)$ = 7.9, p = 0.001, η^2_p = 0.19. Post-hoc paired t-test with a Bonferroni adjustment BASE:TEXT t(35)= -3.73, p=0.002, d=0.62, BASE:READ t(35)=-3.0, p =0.015, d =0.50, TEXT:READ t(35)=1.14 p=0.791, d=0.19.

This indicated that texting and reading were associated with more path deviations in this more difficult gait task (TAN). It should be noted that the effect sizes are small to moderate. Also a few participants had more deviations in the baseline condition than the texting or reading conditions. This may explain in part the large standard deviations.

The difference between the mean deviations during the baseline and during texting conditions were calculated (Table 2) to see if texting has a greater impact on deviations as the gait task got more difficult. ANOVA revealed a main effect in the difference between the BASE and TEXT number of path deviations within the three gait tasks (F(2, 70) = 5.87, p = 0.004, η^2_p =0.14). Post hoc paired t-tests with a Bonferroni adjustment revealed a significant difference between one of three tasks (TUG:STAIR t(35)=0.442, p = 1.00, d=0.07. STAIR:TAN t(35)=2.75, p = 0.028, d=0.46, TUG:TAN t(35)=2.84, p = 0.054, d=0.41). Post hoc analysis revealed only a difference between the TAN task and the stair task indicating that texting did interfere with the gait stability, as the task got more difficult, at least related to the tandem task. However the effect size was only moderate.

Texting Characters Per Second

	BASE	TUG	STAIRS	TAN
CPS	3.71	3.74	3.64	2.92
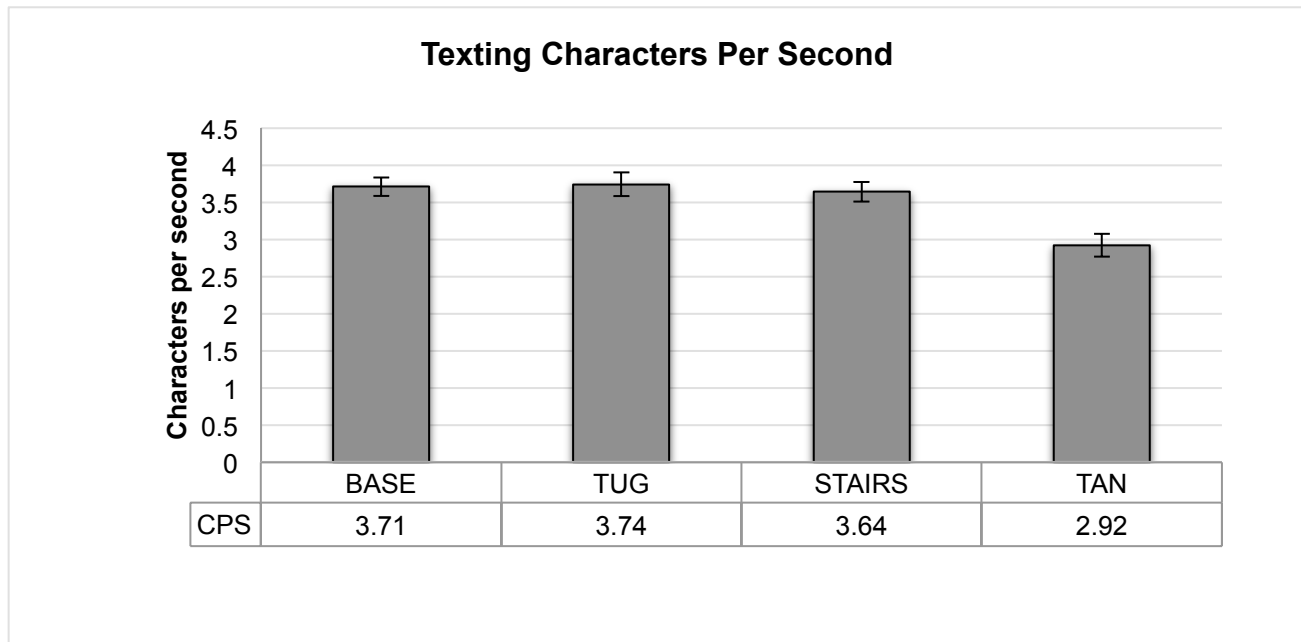
Figure 3. Mean texting characters per second (CPS) during the different tasks: BASE (Baseline texting while standing), TUG (timed-up and go), STAIR (timed-up and go with stairs), TAN (timed-up and go with tandem walking). Error lines indicate standard error. A significant main effect was found.

Among this group of young adults a statistically significant difference in texting characters per second was found between the different gait tasks. See figure 3. The ANOVA revealed a main effect among the conditions F (3, 105) =12.59 p < 0.001, η^2_p =0.27). Post hoc analysis t-tests with a Bonferroni adjustment revealed the following significant pairs: BASE:TAN t(35) = 5.94, p < 0.001, d = 0.99; TUG:TAN t(35) = 4.78, p < 0.001, d = 0.80; STAIR:TAN t(35) = 4.92, p < 0.001, d = 0.82. A moderately large effect size indicates texting speed is practically affected but only in the most difficult gait task.

Among this group of young adults a statistically significant difference in texting errors per second was found between the different gait tasks. See figure 4. The ANOVA revealed a main effect among the conditions F (3, 105) =4.92. p = 0.003, η^2_p =0.12). Post hoc analysis t-tests with a Bonferroni adjustment revealed the   following significant pairs: BASE:STAIR t(35) = -2.82, p = 0.047, d = 0.47; TUG:STAIR t(35) = -2.96, p = 0.033, d = 0.49. The post hoc analysis indicates that the stair task predominately had an effect on texting errors with a moderate effect size.

Texting Errors Per Second

	BASE	TUG	STAIR	TAN
EPS	0.155	0.157	0.282	0.217
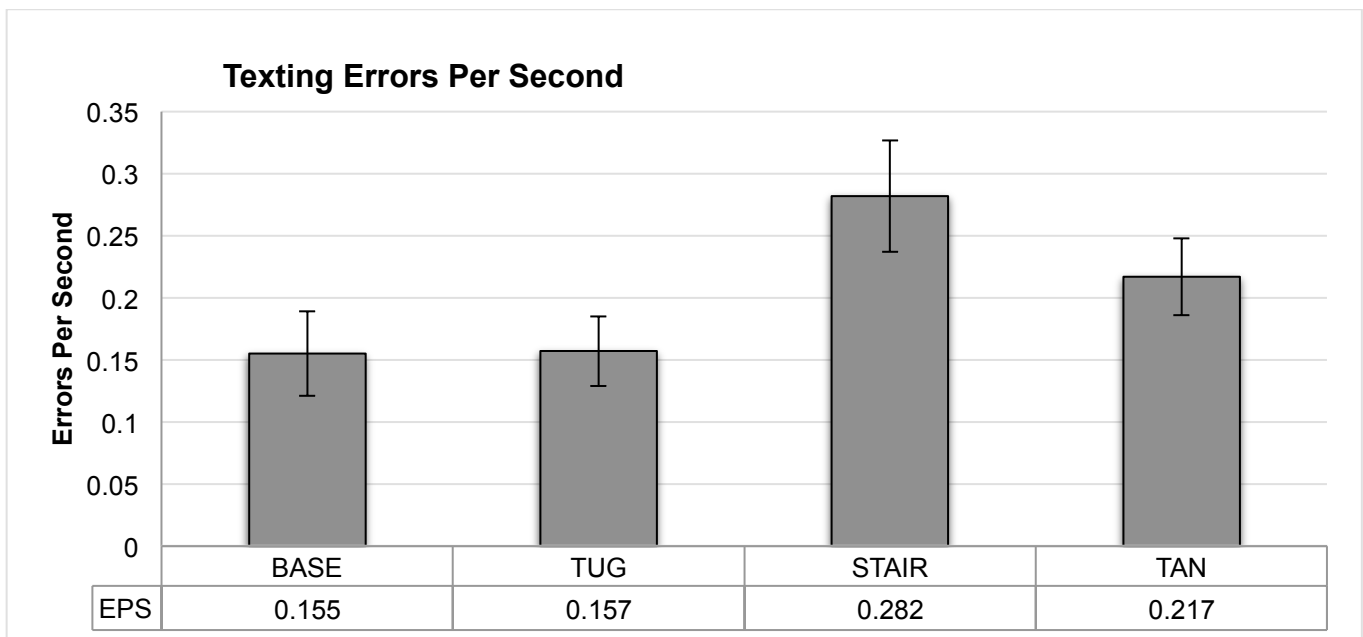
Figure 4. Mean texting errors per second (EPS) during the different tasks: BASE (Baseline texting while standing), TUG (timed-up and go), STAIR (timed-up and go with stairs), TAN (timed-up and go with tandem walking). Error lines indicate standard error. A significant main effect was found.

DISCUSSION

The data did not support our hypothesis that texting could contribute to a greater increase in time to complete the task as the task become more difficult. Within the tasks, texting contributed to slow walking, yet between the tasks (TUG→STAIR→ TAN) texting added a nearly consistent amount to the task despite their progressive difficulty. The other gait parameter, deviations in the task, did not show the same result. Though there was trend for greater number of deviations in the TUG and STAIR task, there was not a significant difference

from the baseline to texting conditions. However during the TAN task there was a significant difference in the number of deviations between the conditions (Baseline and Texting) with a moderate effect size. This 67% increase in the number of deviations suggests that texting interferes with a gait task that has increased postural control demands. However a few subjects did have more deviations in the baseline condition during the TAN task. Despite a practice trial, these deviations could have been due to the novelty of the task, in which more error would be expected. There is also some evidence that some individuals perform better at a motor task when combined with a dual task (13).

Participants in this study also demonstrated decreased gait speed while completing the reading-based task (Figure 1). However, this decrease was observed to a lesser extent than when compared to texting while walking. Similar results were found in the only other study that also compared the impact of texting and reading on gait (14). This suggests that the mental process of composing a sentence and the fine motor task of texting may poses a larger burden than reading when considering dual task activity related to text messaging and walking.

The hypothesis that the gait tasks would interfere with the texting ability was partially supported. The analysis of the texting speed (as measured in characters per second) revealed that as the gait tasks became more difficult, the texting speed decreased. The TAN task is the only one that showed significantly reduced texting speed compared to the BASE, TUG, and STAIR tasks (Figure 3). Thus it appears that the balance demands of the TAN task affected the speed of texting. Though statistically significant, the real world difference was only at the most 0.79 characters per second. Given that most text messages are short, this difference may not have any practical impact. It was also found that as the task became more difficult that the number of errors made increased, and there was a significant increase in the number of errors made on the STAIR (Figure 4). The visual scanning demands of the STAIR task may have had a greater impact on texting errors. It is known that in order to judge stair height before ascending stairs, the eyes scan the step height (16). It might be in order to judge stair height the eyes were taken off the phone, thus causing more errors. Again the practical difference of 0.06 errors per second is very small.

Overall, based on the theory of a limited cognitive capacity to perform dual tasks (7, 16), at least one of the tasks suffered in performance. It appears there is a combination of gait compensation, and depending the gait task, either a compensatory slowing of the texting speed or and increase in either texting errors or gait deviations. Statistical analysis of the data appears to indicate that simultaneous texting and walking bring about motor changes in the speed and skill of the task. Though interesting from a motor control perspective the practical changes are negligible, particularly for the texting task. Prior studies found no significant changes in the number of characters typed per second or errors per text (12, 18). Though this study was different in that a standard text message with the same number of characters was used to more easily compare trials, the changes found were small. Thus it might be concluded that changing the gait demands overall only has a minimal effect on the communication-based task indicating that there may be a prioritization toward the communication-based task.

Though there were statistically significant reductions in speed and path deviations, the actual value of the change was small and needs to be interpreted cautiously. In fact, these subjects, though on average walked more slowly while texting, still had a pace that was considered normal. On one hand, the path deviations are minimal and it could be argued that there is not enough support to prohibit texting while walking. However, in the real world it may only be a single and slight deviation that could result in a fall off a curb, movement into the path of moving vehicle or running into objects all resulting in injury. A limitation of this study is that it does not test these dual task demands in a real world environment. Thus a conclusion as to how important these changes are for safely walking cannot be made. Further studies should look at the texting and walking task in more complex and dynamic environments that may include stationary and movable objects, curbs, holes or complaint surfaces. Because the actual motor changes in gait were practically small, it might be thought that injury occurring during gait and texting relates more to the demands texting has on the attention system rather than on the motor system. Thus the more important motor aspect to explore is perhaps the effect texting has on one's reactive ability after a motor error has occurred.

An interesting note is that the subjects were all young and likely all digital natives. The magnitude of the changes seen in this study may be more profound in those who are not digital natives. An interesting follow-up study would be to compare the gait-texting task of digital natives and those who are not digital natives. A final note of discussion relates to the clinical applicability of this research. Because dual task activities challenge the motor system, as this and other research has shown, using texting in gait training may be a real-world and challenging task, particularly for the young patients. There is evidence to suggest that dual task training improves gait in patients with impairments (9).

In conclusion, this study supports prior research on dual task performance in its suggestion that cell phone texting while walking will produce slower gait. Within the tasks used in this study, the degree of gait slowing does not appear to be practically large nor directly proportional to the difficulty of a gait task. Reading while walking will also result in decreased gait speed, but to a lesser extent than when compared to texting while walking. Additionally, this study suggests that simultaneous texting and walking results in negligible compensatory slowing in texting speed and negligible reduction in texting ability. Given the magnitude of the changes in gait compared to the changes in texting, the study suggests a prioritization toward the communication-based task. This research provides further insight into the complex interactions and resulting changes that occur when an individual taxes their central information processing capacity through dual task efforts such as simultaneous texting and walking.

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