Effects of a Dual-Task on Crossing an Obstacle Versus Initiating Gait

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Abstract. [Purpose] The purpose of this study was to investigate the manner in which young adults step over an obstacle or initiate gait while performing a secondary Stroop task, which requires direct attention. [Subjects] Ten healthy young adults (5 male and 5 female) participated in the study. [Methods] Subjects first completed a Stroop task while standing (baseline) and then initiated gait or stepped over an obstacle as fast as possible with or without a secondary Stroop task. Response times to the secondary task and the gait parameters were measured. [Results] The response time to the secondary Stroop task in the stepping task was longest followed by gait initiation (GI) and standing (p<0.01). The values of bilateral step time and left stance time for stepping with the secondary task were significantly longer than stepping and GI without the secondary task (p<0.05). However, there were no significant differences between tasks in bilateral step and stride length. [Conclusion] This study suggests that even healthy and physically fit young adults have to modify gait parameters in situations where they are engaged in concurrent tasks because of their reduced ability to attend to multiple tasks simultaneously.

Key words: Dual-task, Gait initiation, Obstacle crossing

INTRODUCTION

Attention refers to information processing capacity, space, or resources available to an individual1, 2). Available information processing capacity (or resources) is thought to be limited2), but it may be partitioned to different tasks in a manner determined by the individual. Therefore, if two tasks are performed simultaneously and both require more than the total resources of attention capacity, interference between the two tasks could occur. That is, either one or both tasks could suffer in performance speed or quality, or only one task would be executed while the second task would not. The patterns of interference that are observed between two different tasks may provide important information about the nature of limitations in capacity in different individuals.

Attention increasingly becomes important in balance control in the elderly. This is seen when attention capacity is challenged while walking and simultaneously performing secondary motor or cognitive tasks, or when impairments in postural stability lead to an increased potential for falls3). If the attention capacity of older adults is challenged, then timely corrective or adaptive strategies exercised while walking and standing may be compromised by decreases in information-processing speeds required to perform the tasks4, 5). Alternatively, decreased attention capacity and/or problems of allocating attention resources efficiently may result in similar consequences6, 7). Earlier studies have clearly indicated that attention plays an important role in balance control during
standing and walking. Research investigating the attention capacity in young and elderly groups, however, has mostly focused on the study of steady-state gait or standing. Little is known about the abilities of young and elderly adults to negotiate obstacles while performing secondary attention-demanding tasks from a quiet stance position. Secondary Stroop tasks require direct attention, and in this study, young adults were asked to step over an obstacle from a quiet stance while simultaneously performing a secondary Stroop task.

There are several reasons to perform such an investigation. First, although the causes of falls in the elderly have multiple etiologies, tripping over obstacles is an extremely common cause of falls in this age group (8–12). Next, elderly adults who negotiate obstacles have a significantly higher risk of contact with obstacles when their attention is divided as compared to young adults. Therefore, problems in the performance of secondary tasks while negotiating obstacles may contribute to falls in the elderly. Challenging the attention of young adults while stepping may reveal relationships between attention and obstacle crossing, and these are important factors in the development of fall prevention programs. Further, findings from this study could be used to support the inclusion of dual tasks for fall prevention programs in the clinic. Finally, no studies have looked at the effects of a dual task using a secondary Stroop task on actually crossing an obstacle from the position of quiet stance, a task that would elevate the risk of falls. Therefore, the purpose of this study was to investigate how young adults initiate gait or stepping over an obstacle while performing a secondary Stroop task. In this study, the predicted results of a dual-task paradigm were an increase in response time and an increase in temporal events of gait parameters.

**METHODS**

**Participants**

The study sample consisted of 5 healthy male subjects (mean [SD] age, 22.4 [1.5]; range, 22–25 years) and 5 healthy female subjects (mean [SD] age, 22.8 [0.8]; range, 22–24 years) with no known neurological or orthopedic impairments. All participants signed an informed consent form.

**Instrumentation**

A GAITRite (CIR Systems Inc., Clifton, NJ, USA) was used to measure spatial and temporal events of gait including bilateral measurements of swing time, step time, stance time, step length, and stride length. The GAITRite is an electronic walkway which is 4.6 m long and 0.9 m wide. An obstacle (10 cm in height, 10 cm in breadth, and 120 cm in width) was used for obstacle crossing. The secondary cognitive task involving a Stroop task was used and the response times while initiating gait or stepping over the obstacle were measured. The Stroop task is a psychological test in which a word is printed in a color different from the color expressed by the word’s actual meaning. A stopwatch (CASIO COMPUTER CO., LTD., Tokyo, Japan) was used to measure the response times during the Stroop task.

The experimental set-up is shown in Fig. 1. Subjects first completed versions of Stroop task while standing. For each trial, subjects stood in a predetermined position with each foot on the GAITRite. Subjects then initiated gait or stepped over the obstacle as quickly as possible with the right limb in response to auditory cues. Subjects completed initiation of gait first to familiarize themselves with the experimental protocol. A Stroop task was presented at 5 meters in front of the subject at eye level while initiating gait or stepping. For example, the word “yellow” was displayed in green letters, and subjects were instructed to state the color of the word rather than the actual word itself. A set of 5 different words was presented to each subject. Subjects completed initiation of gait first to familiarize themselves with the experimental protocol. A Stroop task was presented at 5 meters in front of the subject at eye level while initiating gait or stepping. For example, the word “yellow” was displayed in green letters, and subjects were instructed to state the color of the word rather than the actual word itself. A set of 5 different words was presented to each subject. Subjects completed practice trials and approximately 5 successful experimental trials for the following tasks:

1. Initiating gait.
2. Stepping over an obstacle.
3. Initiating gait with a secondary Stroop task.

**Fig. 1.** Experimental set-up. An arrow indicates the direction of movement. RF: right foot, LF: left foot.
4. Stepping over an obstacle with a secondary Stroop task.
The second, third, and fourth tasks were requested in random order.

A two-way repeated analysis of variance (ANOVA) was used to determine the main effects. A single degree of freedom mean contrasts was used to determine the source of any significant effects ($p<0.05$)\textsuperscript{13}. The independent variables were initiation condition (gait initiation (GI) and stepping) and the secondary Stroop task. The dependent variables included bilateral swing time (the time between swing toe-off and next heel contact), step time (the time of the completion of a right or a left step), stance time (the time between heel contact and toe-off of the same foot), step length (the distance between successive heel contacts of the two different feet), and stride length (the distance between two successive heel contacts of the same foot). One-way repeated ANOVA was used to examine the difference between the response times of the three types of tasks (standing, GI and stepping). The response time to a Stroop task was measured from the onset of the auditory cue to completion of a set of 5 different words in the Stroop test. SPSS 14.0 KO (SPSS, Chicago, IL USA) was used for statistical analyses.

**RESULTS**

Comparisons of changes in behavioral, spatial, and temporal responses in reaction to a secondary Stroop task were analyzed in young adults. This allowed us to elucidate whether subjects were able to maintain gait parameters while crossing an obstacle, or initiating gait while simultaneously performing a secondary task. Significant changes were noted in temporal events such as bilateral step time and left stance time. The mean values for temporal and spatial events for each condition are summarized in Table 1 and Table 2. Response time data demonstrated significant differences between time during dual tasks and time during baseline, or standing.

There was a significant main effect in response times among the three conditions of standing, GI, and stepping ($p<0.01$) (Table 3). Multiple comparisons revealed that there were significant differences in response times across all comparisons. Among the three tasks involving a secondary task, the mean response time during the standing trials was significantly shorter than those in GI and stepping ($p<0.01$). The response time during stepping was longest compared to the other tasks.

There were main effects for the secondary task for right step time ($p<0.05$) and left stance time.
Follow-up tests showed that the value of right step time for stepping with the secondary task was significantly longer than the stepping and GI without the secondary task ($p<0.05$, respectively). In addition, the value of left stance time for stepping with the secondary task was significantly longer than GI without the secondary task ($p<0.05$). There were also main effects for stepping on the left step time ($p<0.05$). A follow-up test revealed that left step time in stepping with the secondary task was significantly longer than GI without the secondary task ($p<0.05$). However, right stance time was not significantly different among the tasks. In addition, left swing time approached significance ($p=0.058$) for the stepping task. In contrast, there were no significant differences among right swing times, and no significant differences among primary tasks for bilateral stride and step length.

**DISCUSSION**

The primary goal of this study was to examine the effects of the secondary Stroop task while crossing an obstacle or initiating gait on the temporal and spatial gait parameters. In general, subjects appeared to modulate gait parameters differently in response to concurrent motor and secondary Stroop tasks. Overall, slower response times and increases in bilateral step time and left stance time were observed for subjects while performing the secondary Stroop task while crossing an obstacle or initiating gait.

It is hypothesized that the ability to attend to one task declines when a second task is added. Both tasks could suffer in performance speed and quality, or only one task can be executed while the second task cannot. Thus, it was expected that the greatest interference between concurrent motor and secondary Stroop tasks in the present experiment would occur during the performance of a stepping task while responding to secondary Stroop task. This would occur due to competition for attention between the two tasks. The results revealed that the greatest interference occurred in the stepping task while secondary task was demanded. The mean response time during the stepping trials was significantly slower than those in GI and standing trials. These results suggest that response time increases as task parameters are manipulated in order to make the task more demanding. These results are consistent with previous studies, which reported that divided attention during negotiation of obstacles degraded obstacle avoidance abilities of both elderly and young adults. For example, Teasdale et al. reported that young and elderly adults had increased reaction times during conditions where vision and/or proprioception were disturbed, and that elderly adults were more affected by the absence of vision.

Appropriate scaling of gait parameters during obstacle crossing is crucial to ensure a safe and efficient foot crossing. The stance limb must also provide a stable base from which to cross the obstacle. The subjects demonstrated significantly longer left stance times while performing the stepping task with a concurrent secondary Stroop task than during GI. The difference in mean stance times between the two motor tasks was 431 ms. The increase in stance time can be attributed to the overall ability of the subjects to maintain pelvic obliquity by contraction of the gluteus medius.

Bilateral step time was also significantly longer while performing the stepping task with a concurrent secondary Stroop task than during GI. Subjects presumably modulated limb trajectory for appropriate toe clearance in order to cross the obstacle. A previous study revealed that increases in toe clearance and step times used to cross an obstacle were needed in order to safely cross the obstacle as compared with GI. In the current study, the difference in right and left step times between the stepping task with a concurrent secondary Stroop task and GI was 454 ms and 160 ms, respectively. Interestingly, only the stepping task with a concurrent secondary Stroop task significantly differed from GI in bilateral step time and left stance time. However, there was little change in the spatial events across all conditions (Table 2). Subjects predominantly changed the secondary task but not the primary task in the spatial events such as bilateral step and stride length. These results are

<table>
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<th>Table 3. Means (SD) for response times (ms)</th>
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<td>Standing</td>
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<td>Response times*</td>
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<td>* Significant main effect for the Stroop task condition ($p&lt;0.01$).</td>
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<td>1 Significant difference between standing and gait initiation.</td>
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<td>2 Significant difference between standing and stepping.</td>
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<td>3 Significant difference between gait initiation and stepping.</td>
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SD: Standard deviations.
consistent with findings by other researchers\textsuperscript{16, 20}). The findings suggest that GI with a concurrent secondary cognitive task does not require complete attention compared to a stepping task with a concurrent cognitive task.

There are limitations to current study. This study had a small sample size. Further, it was unable to examine the exact timing and spatial events of gait parameters during the interference generated by motor tasks with concurrent cognitive tasks because the gait parameters displayed by GAITRite were averages over time.

In conclusion, the results of this study provide an increased understanding of the implementation of dual tasks while stepping over obstacles. The majority of obstacles one might encounter in daily life enter the field of view in a sudden manner and attention is seldom fully focused on such obstacles. Our findings indicate that even young adults had to modify their gait parameters in situations with concurrent cognitive tasks because of their reduced ability to attend to multiple tasks simultaneously. It will be interesting to investigate the effects of age and dual tasks while stepping over obstacles. Further work is necessary to examine the strategies that older adults may adopt in order to effectively perform the dual tasks.

REFERENCES