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Initiation of Body Segment Reorientation in Steering is not Altered While Dual Tasking

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Abstract

Changing the direction of locomotion, often referred to as "steering", is an integral component of human locomotion. This study sought to investigate the role of cognition in steering using a dual task paradigm in healthy young and healthy older adults. Twenty-five healthy young adults and nineteen healthy older adults completed a 900 walking turn at a comfortable pace under single and dual task conditions. Dependent variables included the time taken to turn and the turn onset of the head, trunk, and pelvis segments. Results indicate dual tasking increases the time taken to turn but does not alter the sequence of initiation of segment reorientation into the turn. The effects of aging on these behaviors were minimal. Most notable was that the older adults did not slow their turns as much as the young adults did during dual tasking. These results suggest that initiation of segment reorientation is independent of cognitive influence but that increased cognitive load is considered when planning movement time.

Key Words: Steering; Turning; Adaptive Locomotion; Older Adults; Dual Task;

Introduction

An important component of human locomotion is the ability to adapt to the environment. Redirecting walking direction (a.k.a. steering) is a commonly performed activity that allows an individual to go around obstacles, turn corners, and avoid collisions [1-6]. Unfortunately, steering is also a movement that creates substantial difficulty in populations with reduced mobility. In particular, difficulties in steering coordination occur in older adults with a history of falls [7, 8, 9], individuals who have survived a stroke [10, 11], and individuals with Parkinson's disease [12, 13].

Of recent interest in understanding steering control, is the role of cognition in the execution of turning. This is of great importance as humans rarely move in the environment without performing concurrent cognitive tasks (e.g., carrying on a conversation either in person or on a mobile telephone). Little research has addressed this question, but research has indicated a significant role of cognition in the planning and execution of turning tasks [14]. In particular, increased time to turn and adoption of more cautious gait parameters (e.g., wider step width and increased single support time) have been observed in older adults and stroke survivors while steering under a dual task paradigm [14]. Dual task paradigms challenge attention capacities by performing a secondary cognitive task while simultaneously performing a primary motor task. When two stimuli require processing at the same time, a "bottleneck" arises, resulting in a delay of one of the responses [15]. The hypothesis regarding dual tasking in gait is that if gait is an automatic activity that does not require deliberate attention, then dual tasking will not affect gait parameters. However, if dual tasking affects gait parameters, then some level of attention is required by the gait task itself. We used a similar hypothesis to examine the role of cognition in steering.

A critical component in studying steering coordination is the onset of segment reorientation at the initiation of the redirection. Segment reorientation is well defined in steering control literature [3, 5, 6, 16, 17, 18, 19] and disruption to the sequence is a significant indicator of steering difficulties [9, 13]. Therefore, to better understand the role of cognition in steering control we must know how cognitive load influences the sequence of body segment reorientation.

The purpose of the current study was to measure the sequence of reorientation of the body segments in steering control under a dual task paradigm. The current study examined steering control in a group of healthy young adults and a group of healthy older adults to understand whether the healthy aging process affects the interaction of steering control and cognitive load. We hypothesized that if steering requires significant attentional resources, participants would increase turn time and display a significant delay in the turn onset of body segment reorientation under dual task conditions. In addition, we expected that older adults might also display interruption to the sequence of body segment reorientation. Specifically, the body may reorient as a single unit (en-bloc) because of a need to simplify motor control under a dual task condition. Use of this strategy would indicate that cognitive decline associated with healthy aging [20] influences the ability to coordinate the body's segments during turning activities.

Materials and Methods

Participants

Twenty-five healthy young adults and nineteen healthy older adults participated in the study (Table 1 provides demographics). Sample size was determined using G power 3.1 with a set α level of 0.05, with a medium effect size (0.25) determined from prior research findings [16, 21-24], with a desired β of 0.20 and a correlation value among the dependent variables of 0.50 [21].

Age Group(N)	Age	Weight(kg)	Height(cm)
	Young		
Female(12)	22.0±2.7	60.7±10.1	162.3±5.8
Male(13)	23.8±2.8	89.4±15.2	178.8±6.1
Total(25)	22.9±2.9	76.2±19.6	170.4±10.9
	Old		
Female(10)	70.7±3.7	65.9±9.9	162.3±8.3
Male(9)	73.4±6.3	80.9±9.5	175.3±6.6
Total(19)	72.1±5.3	70.4±10.5	167.1±9.1

Table 1: Average age, weight and height for the two age groups

A general health questionnaire [25] was administered prior to inclusion in the study to ensure healthy volunteers were free of any neurological disorders (e.g., vertigo and hearing disorders) and did not have any medical conditions that contraindicated participating in the study (e.g., heart conditions). Human participant ethics approval was obtained from the University of Texas at El Paso and all participants provided informed written consent (IRB Reference # 521597-2).

Study design

The study used an ABCA-ACBA control group design with independent variables task condition (*TASK*) and age group (*AGE*). Dependent variables included the time taken to complete the turn (Turn Time) and rotation onset of the body segments. To determine the effects of TASK participants performed three types of activities. (A) baseline motor task where participants walked and made a 90^o turn; (B) dual task where participants walked and made a 90^o turn while performing serial 7 subtractions out loud; (C) single task serial 7 subtractions performed out loud for 45 seconds while sitting (approximately the time to finish the walking and turning task). The score on the single task serial 7 (C) was used to control for differences in the participants' individual ability to perform serial 7 subtractions. Evaluation of performance on serial 7 subtractions was obtained by subtracting the number of mistakes from the number of subtractions made in the given time. To control for practice and fatigue affects, the order of B and C were counterbalanced between the research participants.

Procedures

Prior to the experimental trials, participants walked on a straight path with maximum length 5 meters (5 trials). Data from straight path walking trials were used to determine the turn onset of body segments as per previously published methods [16, 21].

The experimental trials involved walking along a straight path and redirecting the walking trajectory to the right or left (90^o) around a marker placed in the center of the walkway. To control for effects due to turn direction both right (5 trials) and left turns (5 trials) were randomized. Participants were instructed to walk at their normal pace. The instructions for the dual task condition (B) were to walk and make a 900 turn at a comfortable pace while performing the serial 7 subtractions out loud. No instruction for priority of tasks was given.

Experimental design

The single task condition (A) was performed before and after the dual task condition for all participants to control for threats to internal validity such as fatigue, testing and practice effects. The dual task condition significantly increased turning times in both YA and OA (Fig. 1). In addition, turn time returned to baseline following the dual task condition (Fig. 1). These results point to the strong effect of the dual task on turn time and support that the effects observed in the study were not due to fatigue or testing and practice effects. As the two A conditions were not statistically different, they were collapsed for further analysis.

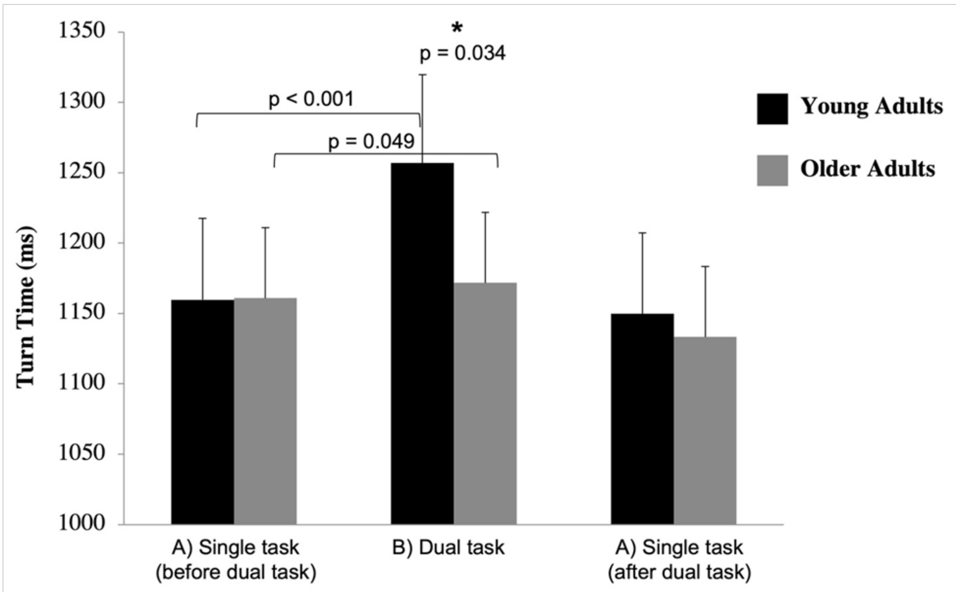

Figure 1. Summary of turn times (mean+ standard deviation) for the single and dual task conditions in younger and older adults. Note the presence of the two single task conditions (A). This was a part of the ABCA-ACBA study design. Significant differences were observed between the A and B conditions as indicated by brackets. In addition, a significant effect of age of turn time during the dual task conditions was observed (indicated by asterisk *)

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The serial 7s score obtained from the single cognitive task condition (C) was intended as a covariate for statistical analysis to control for differences in the participants' ability to perform the serial 7 subtractions while sitting. One of the assumptions of covariate analysis is that the covariate must have a linear relationship with the dependent variables [26]. On preliminary analysis, serial 7 scores had no significant relationship to the dependent variables, and therefore were not included in further statistical analysis.

Measures and instrumentation

Three-dimensional kinematic data (120 Hz) was collected using an eight-camera motion capture system (Vicon, Oxford, UK). A whole body marker configuration as per the Plug-In gait model was used (Vicon Oxford, UK). Analysis of segment kinematics focused on rotations about the yaw axis (vertical axis) to define reorientation into the turn. Data reduction was performed as per previously published methods [16]. Onset of rotation for the head, trunk, and pelvis segments in milliseconds were dependent variables. In addition, turn time was calculated from one-step prior to one-step following the turn.

Statistical Analysis

Mixed model repeated measures MANOVAs determined the effects of the independent variables TASK and AGE on the rotation onsets of the head, trunk and pelvis segments and on turn time. Within-subjects variable TASK (two levels: single motor task (A) and dual task (B)) and between-subjects variable AGE (two levels: young adults (YA) and older adults (OA)). Post-hoc analysis was conducted using Bonferroni pairwise test.

Results

Effects of age and task condition on turning time

A significant interaction effect of TASK and AGE on turning time was found ($F_{(1, 42)} = 6.419$, $p = 0.015$, $\eta^2 = 0.127$). This result indicates that the dual task condition affected the turn time differently in the young and older adult groups. Further post-hoc one-way ANOVA examined the effects of AGE for each TASK independently. For the single motor task condition (A), no significant difference in turn time due to AGE was found ($F_{(1, 42)} = 0.116$, $p = 0.734$) (Fig. 1). For the dual task condition (B), a statistically significant difference due to AGE was observed ($F_{(1, 42)} = 4.816$, $p = 0.034$). The younger adults took a greater amount of time to turn when compared to the older adults in the dual task condition (Fig. 1).

Effects of age and task condition on turn onsets of the head, trunk, and pelvis

No significant interaction of TASK and AGE on the turn onset of the head, trunk and pelvis segments was found ($F_{(4, 39)} = 2.397$,p $= 0.067$). However, a significant main effect of AGE on the turn onsets of the segments was observed ($F_{(4. 39)} = 3.293$, $p = 0.020$, $\eta^2 = 0.252$). Based on this main effect, we examined the effects of AGE on segment onset for the single motor task (A) and dual task (B) independently.

Effects of task condition on the turn onsets in healthy young adults

No significant effect of TASK was observed for turn onsets of eyes, head, trunk and pelvis in healthy young adults. ($F_{(4, 21)} = 0.774$, $p = 0.555$). Thus, the dual task condition did not affect the turn onset of the head, trunk and pelvis in young adults (Fig. 2).

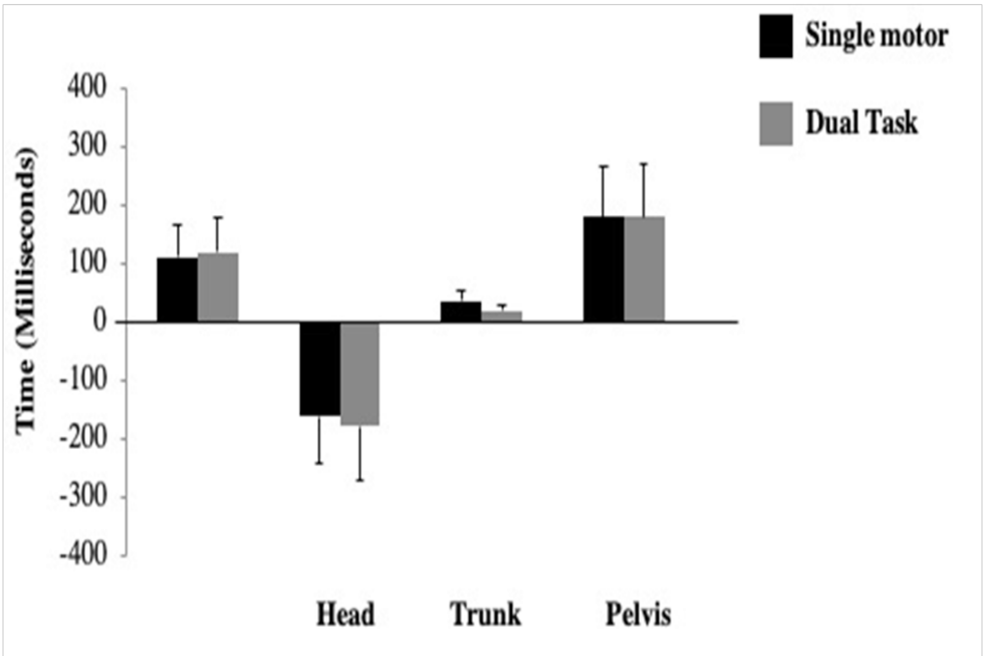

Figure 2. Summary of segment onset times (mean + standard deviation) for younger adults. Note that no significant differences were observed in younger adults between single and dual task conditions.

Effects of task condition on the turn onsets in healthy older adults

A significant main effect of TASK was observed for turn onset of the head, trunk and pelvis in healthy older adults ($F_{(4,15)} = 5.077$, $p = 0.008$, $\eta^2=0.559$). Bonferroni corrected pair-wise comparisons revealed significant differences in the turn onsets of head, trunk, and pelvis (Fig. 3). Thus, the dual task condition affected the turn onsets of various body segments in the older adult group.

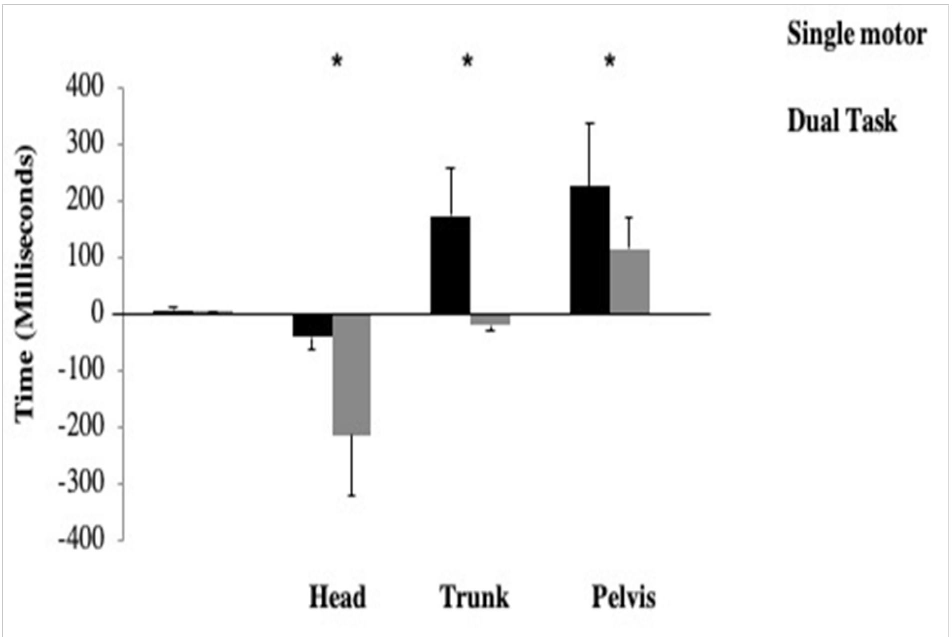

Figure 3. Summary of segment onset times (mean + standard deviation) for older adults. Significant differences between the single and dual task conditions are indicated.

Discussion

The purpose of this study was to determine whether dual tasking influences body segment coordination during walking turns (a.k.a. steering) in healthy younger and older adults. Overall, the results of the study did not support our hypotheses that dual tasking delays segment reorientation. In contrast, while turn time increased during dual tasking (Fig. 1), segment coordination was unaltered by the dual task condition (Fig. 2). In addition, older adults did not display interruption to segment control under dual task conditions suggesting that cognitive decline associated with healthy aging does not influence the ability to coordinate the body's segments during turning activities (Fig. 3). The most notable difference between the two age groups was that older adults completed the turn more quickly overall than younger adults.

Effects of age on steering under single motor task conditions

Under single motor task performance, there were few differences between steering behavior in young and older adults. Turn time was not significantly different between the young and older adult groups (Fig. 1). While turn onset times of the head, trunk and pelvis in older adults occurred later when compared to younger adults, only the trunk onset time was statistically significant. Delayed segment reorientation suggests older adults tend to take more time to plan segment coordination when available, however; it is unlikely this is critical to their steering control, as increased delays were not observed under dual task conditions.

Effects of dual tasking on steering in healthy young adults

Under dual task conditions, healthy young adults took significantly longer to complete the turn, however; there were no differences in the timing of when the body segments began reorientation to the new direction of travel (Figs. 2). Findings of increased time to complete a task are consistent with previous literature on the effects of dual tasking on gait in young adults. Specifically, reduced velocity may be a strategy to account for increased processing time of sensory information under increased cognitive load [27-31]. The most significant finding of this study is that while younger adults increased turn time while dual tasking, the initiation of body segments remained unaltered. These results suggest that the sequence of segment movement occurs independently of cognitive influence. These conclusions support the hypotheses that body segment coordination is a synergy type system belonging to phylogenetically old neural mechanisms and is a basic component of the human locomotor repertoire [2, 17, 21].

Effects of dual tasking on steering in healthy older adults

Turn onset for the head, trunk and pelvis segments occurred earlier in the dual task condition for older adults (Fig. 3). The time taken to turn was also significantly increased when dual tasking, however not to the extent that was observed in younger adults (Fig. 1). In fact, when comparing segment initiation between older and younger adults, it was during the dual task condition that the older adults' onset of body segment rotation closely resembled those observed in young adults (Fig. 2 & 3). This finding was counter to what we hypothesized.

It was hypothesized that older adults might display greater disruption to steering control compared to younger adults in the dual task condition. A number of studies have reported a decline in motor task performance in healthy older adults due to dual tasking [32-35]. However, this was not the case in the current study. In fact, the older adults' steering control became more reflective of the younger adults' control while dual tasking. A potential reason for this result could be that dual tasking forced older adults to pay more attention to their steering task. Older adults have been found to prioritize stability of gait when walking and performing a cognitive task using a "posture first" strategy to avoid hazards and prevent falls while walking [28, 30, 36]. It might be that the older adults in the current study, although they were not asked to, prioritized the steering task over the serial 7 subtractions task. A 'posture first' strategy could also help to explain the faster turn times, when compared to YA turn times, of OA in the dual task condition. This observation may indicate a tendency to rush the movement in order to perform both tasks.

Overall, this is the first study to examine the role of attention in the top-down control of body segment coordination of steering in a healthy young and older adult group. The results of this study provide evidence that initiation of body segment coordination during steering is not influenced by cognitive load but that cognitive load may have influence during the planning of movement time. Increased time to turn is a strategy adopted to account for the increase in sensory information processing and motor planning as a result of increased

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cognitive load [27-31]. This is a significant finding and provides a substantial addition to the current literature on steering control. In addition, the current study suggests that the healthy aging process does not significantly alter the amount of cognitive involvement in steering control. However, this finding should be interpreted with due caution, as these results do not suggest that cognitive impairment does not affect steering control. In particular, the older adults involved in this study represented a group that were recreationally active and did not have any mobility difficulties. As such, further study of the effects of dual taking on steering control in older adult groups with mobility difficulties and/or measured cognitive impairments would be valuable. In conclusion, the results of the current study provide evidence that investigating steering control under dual task paradigms may provide greater insight into the neurological mechanisms that sub-serve steering control.

Declaration of Interest: No potential conflict of interest.

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