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Short communication

Factors influencing dynamic prioritization during dual-task walking in healthy young adults

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ABSTRACT

Appropriate prioritization during dual-task walking is necessary to achieve task goals and maintain walking stability. We examined the effects of increased walking task difficulty on dual-task walking prioritization in healthy young adults. Walking under simple usual-base conditions was similar between equal-focus and cognitive-focus instructions, but these differed from walking-focus instructions, consistent with cognitive task prioritization. In contrast, narrow-base walking was similar between equal-focus and walking-focus instructions, but these differed from cognitive-focus instructions. This shift in prioritization with increasing walking task difficulty suggests that prioritization is dynamic and flexible.

1. Introduction

During dual-task walking, tasks must be prioritized appropriately to achieve goals while maintaining safety. This requires flexible allocation of cognitive resources like attention [1,2]. The posture-first hypothesis suggests that postural tasks are prioritized at the expense of concurrent tasks to maintain stability and prevent falls, though evidence for this is conflicting [3,4]. Shumway-Cook et al. proposed that posture-first is not an invariant strategy, noting that "the allocation of attention during the performance of concurrent tasks is complex, depending on many factors including the nature of both the cognitive and postural task, the goal of the subject, and the instructions" [3]. This implies that task prioritization is flexible and depends on a variety of individual, task, and environmental factors. This study examined how increased walking task difficulty affects prioritization during dual-task walking in healthy young adults (HYA). We anticipated cognitive task prioritization during simple usual-base walking and walking prioritization during more challenging narrow-base walking.

2. Methods

Fifteen HYA (mean [SD] age: 26.4 [4.3] years; 6 males) participated. Informed consent was obtained in accordance with institutional review board procedures.

An auditory Stroop test [5,6], consisting of the words "high" and "low" said in a high or low pitch, was performed with instructions to "state the pitch as quickly and accurately as possible." After training, three blocks (20 stimuli/block) of seated single-task and two blocks of each dual-task condition were performed. Outcomes were response latency (time from stimulus onset to response onset) and response accuracy (percentage of total responses that were correct).

Participants walked with a usual-base (UB) and a narrow-base (NB) of support (50% pelvic width) [7]. Instructions were "walk as quickly as possible" for UB walking and "walk as quickly and accurately as possible" for NB walking. A Qualisys Motion Capture system (Qualisys, Gothenburg, Sweden) recorded the position of markers on the feet, legs, pelvis, and trunk. Gait speed was measured for both conditions. NB step accuracy was the percentage of total steps that were accurate (the ankle marker, at heel strike, was on or within the path boundary).

Dual-task conditions were: (1) equal-focus (DT_{equal}): "focus on both tasks equally;" (2) cognitive-focus (DT_{cog}): "focus on the cognitive task;" and (3) walking-focus (DT_{walk}): "focus on walking." The DT_{equal} condition was performed first to eliminate an influence of instructions, with randomization of walking task (UB, NB) order between participants. For the remaining conditions, the order of walking task (UB, NB) and instructions (DT_{walk}, DT_{cog}) was randomized.

The dual-task effect measures relative change in dual-task compared to single-task performance [8,9]. A negative value represents a dual-task cost (decrement in dual-task compared to single-task performance). Composite dual-task effects were calculated for the cognitive task and walking to account for potential within-task trade-offs [8]. Response latency and response accuracy dual-task effects were summed for the cognitive dual-task effect. Gait speed defined the UB walking dual-task effect, while both speed and step accuracy dual-task effects were summed for the NB walking dual-task effect.

Prioritization was first assessed by comparing DT_{equal} to single-task performance. Cognitive performance was assessed using analysis of variance (ANOVA; SPSS Statistics 17.0, Chicago, USA) with one factor, condition (single-task, UB, NB). Gait speed was assessed using ANOVA with two factors, condition (single-task, dual-task) and walking task (UB, NB). NB step accuracy in single-task versus DT_{equal} conditions was assessed using a *t*-test. Second, DT_{equal} was compared to DT_{cog} and DT_{walk} performance. The effects of instructions and walking task were examined using ANOVA with two factors, instructions (DT_{equal}, DT_{cog}, DT_{walk}) and walking task (UB, NB). NB step accuracy was assessed using an ANOVA with one factor,

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instructions. Significance was set at $\alpha = .05$, with Bonferroni adjustment for multiple post hoc comparisons.

3. Results

Condition influenced response latency (main effect: $F(2,28) = 9.659$; $p = .001$), with shorter latencies under single-task compared to both UB DT_{equal} (Fig. 1A; post hoc: $p = .007$) and NB DT_{equal} walking (post hoc: $p = .002$). Condition did not affect response accuracy (Fig. 1B; main effect: $p = .88$). Gait speed was faster in single-task versus DT_{equal} conditions (Fig. 1C; main effect: $F(1,14) = 4.961$; $p = .04$) and for UB versus NB walking (main effect: $F(1,14) = 12.634$; $p = .003$), with no interaction ($p = .63$). NB step accuracy was similar in single-task and DT_{equal} conditions (Fig. 1D; $p = .25$; Table 1).

Instructions affected response latency (main effect: $F(2,28) = 26.600$; $p < .001$). DT_{equal} latencies were longer than DT_{cog} (post hoc: $p = .001$) and shorter than DT_{walk} (post hoc: $p < .001$). Walking task did not affect response latency (main effect: $F(1,14) = 3.479$; $p = .08$), and there was no interaction ($p > .44$). Neither instructions (main effect: $p > .35$) nor walking task (main effect: $p = .18$) influenced response accuracy, with no interaction (both $p = .51$).

Both instructions (main effect: $F(2.28) = 5.549$; $p = .009$) and walking task (main effect: $F(1,14) = 10.377$; $p = .006$) affected gait speed, with an interaction ($F(2,28) = 5.939$; $p = .007$). For UB walking, DT_{equal} speed was similar to DT_{cog} (post hoc: $p = .38$) but slower than DT_{walk} (post hoc: $p = .008$). Instructions did not affect NB speed ($p > .11$). Instructions influenced NB step accuracy (main effect: $F(2,28) = 4.598$; $p = .02$). DT_{equal} step accuracy was similar to DT_{walk} ($p = .46$) but higher than DT_{cog} (post hoc: $p = .01$).

Instructions influenced cognitive dual-task effects (main effect: $F(2,28) = 26.061$; $p < .001$) but walking task did not (main effect: $F(1,14) = 3.988$; $p = .07$), with no interaction (Fig. 2A and C; $p = .37$). The cognitive dual-task cost in the DT_{equal} condition was greater than DT_{cog} (post hoc: $p = .001$) and smaller than DT_{walk} (post hoc: $p < .001$). Walking dual-task effects were influenced by instructions (main effect: $F(2,28) = 6.251$; $p = .006$) and task (main effect: $F(1,14) = 13.628$; $p = .002$), with a significant interaction (Fig. 2A and B; $F(2,28) = 3.713$; $p = .04$). For UB walking, the dual-task cost in the DT_{equal} condition was similar to DT_{cog} (post hoc: $p = .35$) but greater than DT_{walk} (post hoc: $p = .007$), consistent with cognitive task prioritization. NB walking showed the opposite pattern. The DT_{equal} dual-task cost was similar to DT_{walk} (post hoc: $p = .62$) but smaller than DT_{cog} (post hoc: $p = .02$), consistent with walking prioritization.

4. Discussion

These results indicate that the cognitive task was prioritized during simple UB walking while walking was prioritized during more complex NB walking, consistent with the concept of dynamic prioritization.

A number of methodological choices should be noted. First, instructions were to focus equally on both tasks rather than providing no instructions. Our results were similar to previous research using non-instructed conditions, suggesting similar effects [10]. Secondly, participants walked at their fast-as-possible

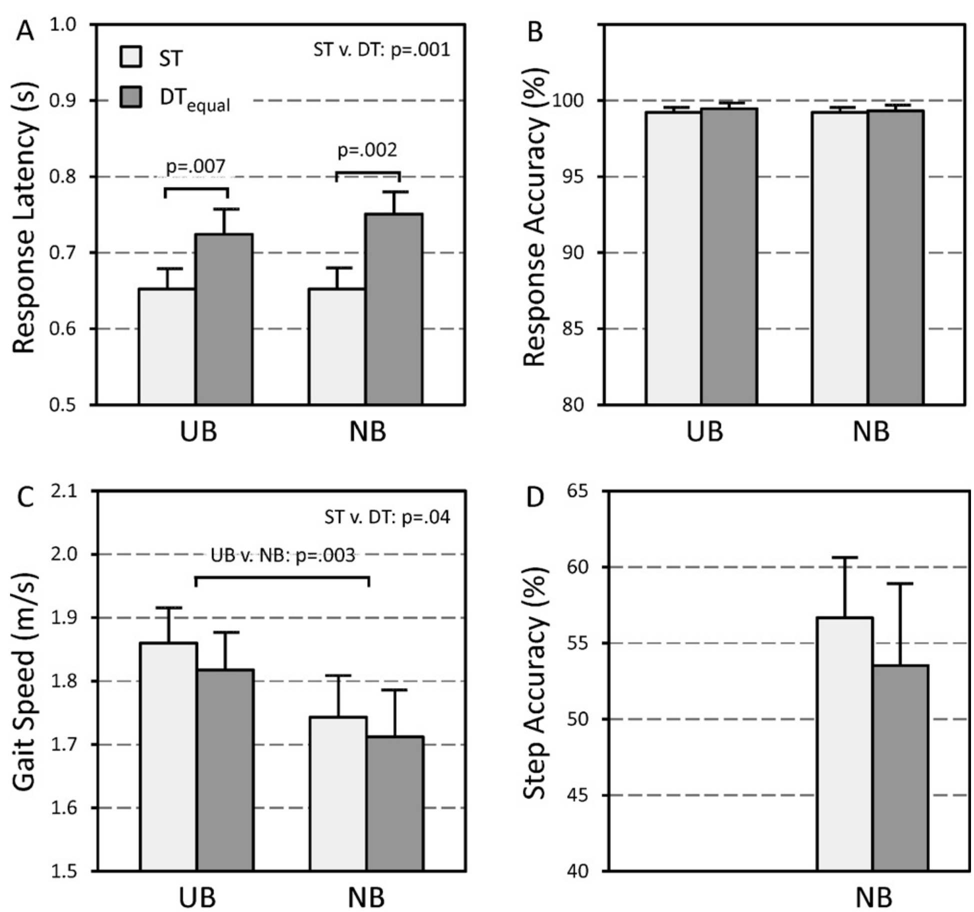

Fig. 1. Cognitive task response latency (A), cognitive task response accuracy (B), gait speed (C) and NB step accuracy (D) under single-task and dual-task walking conditions, with instructions to focus on both tasks equally (DT_{equal}). Symbols represent means, and bars represent standard errors (note: standard errors for response accuracy were $< 1\%$ in all cases). ST: single-task condition; DT: dual-task equal focus condition; UB: usual-base walking; NB: narrow-base walking.