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Sensory and motoric influences on attention dynamics during standing balance recovery in young and older adults

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Abstract

This study investigated impact of attention on the sensory and motor actions during postural recovery from underfoot perturbations in young and older adults. A dual-task paradigm was used involving disjunctive and choice reaction time (RT) tasks to auditory and visual stimuli at different delays from the onset of two types of platform perturbations (rotations and translations). The RTs were increased prior to the perturbation (preparation phase) and during the immediate recovery response (response initiation) in young and older adults, but this interference dissipated rapidly after the perturbation response was initiated (<220 ms). The sensory modality of the RT task impacted the results with interference being greater for the auditory task compared to the visual task. As motor complexity of the RT task increased (disjunctive versus choice) there was greater interference from the perturbation. Finally, increasing the complexity of the postural perturbation by mixing the rotational and translational perturbations together increased interference for the auditory RT tasks, but did not affect the visual RT responses. These results suggest that sensory and motoric components of postural control are under the influence of different dynamic attentional processes.

Keywords

Posture; Balance; Attention; Aging

Introduction

Dual-task paradigms have been used to demonstrate that a competition for cognitive resources exists during postural challenges (Redfern et al., 2009; Boisgontier et al., 2013; Little and Woollacott, 2014). Additionally, recent imaging studies have shown that higher cognitive resources are necessary to maintain balance and integrate the functional systems

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involved in sensory-motor processing, especially in challenging environments (Chang et al., 2013; Miller et al., 2002). This is particularly true in older adults, as they may recruit additional cognitive resources to maintain balance compared to young (Goble et al., 2010; Van Impe et al., 2009, 2011). These insights into cognition and balance shine new light onto another potential contributor to fall risk in older adults. Not only do older adults have decreased balance function that increases fall risk, age-related changes in executive function also contribute to increased fall rates in this population (Kearney et al., 2013; Lord et al., 1992; Redfern et al., 2009; Hauer et al., 2003).

Attentional costs related to postural performance in older adults has been investigated through dual-task experiments that measure the interference between postural control and cognitive tasks. Dual-task paradigms have been used with a variety of cognitive tasks being performed concurrently with different postural tasks (Little and Woollacott, 2014; Redfern et al., 2009). The cognitive tasks usually include an information processing task such as reaction time (RT) tasks (auditory or visual), executive function tasks, or memory tasks. Some investigations have found significant interference effects (Doumas et al. 2008; Hadjistavropoulos et al. 2012; Little and Woollacott 2014; Muller et al. 2004; Redfern et al. 2001, 2009) while others have not (Maylor et al. 2001; Norrie et al. 2002; Swan et al. 2004). These conflicting results are most likely due to differences in the type of task, the sensitivity of the task to measure changes, the instructions given, and the nature of the cognitive resources utilized (Little and Woollacott 2014; Redfern et al. 2009; Mitra and Fraizer, 2004). However, there is some evidence that the sensory modality of the tasks can also have an effect. Muller et al. (2004) found that perturbations had a greater interference on auditory RT tasks compared to visual RT tasks, and they suggested a sensory selection effect on the interference between the postural response and the information processing task occurs.

The temporal aspects of attention involvement in balance recovery have been investigated through the use of platform perturbations and various concurrent tasks (Brown et al. 1999; Rankin et al. 2000; Redfern, et al. 2002). Competition for attentional resources has been found before (preparation phase) and during the response to the platform movements (execution phase) (Brown et al., 1999; Redfern et al., 2002). The attentional dynamics during perturbations are rapid, however, and resolve in less than 300 ms after which no interference can be detected. (Redfern et al., 2002). Thus, attention is necessary for postural control, but can be focused dynamically (Muller et al., 2004; Redfern et al., 2002). What is not known is differential influence of attention on the sensory and motoric components of balance recovery in the preparatory phase and the execution phase.

This study explores gaps in our understanding of the dynamics of attention during a postural recovery in young and older adults. The first gap is the differential influence of attention on the sensory and motoric components of balance recovery in the preparatory phase and the execution phase. Specifically, the interaction of sensory processing and motor selection in response to a postural perturbation. The second gap is how sensory modalities of information processing tasks influence attention allocation, particularly to the preparatory phase.

A dual-task paradigm was used involving RT tasks as the information processing task and underfoot postural perturbations requiring a recovery response. The experiment had the following set of aims: (1) Replicate our prior findings that interference between information processing and postural challenge was confined to immediately prior to and shortly after the onset of the postural challenge and that this effect was magnified in older relative to younger participants; (2) Demonstrate that the sensory modality of the information processing task influences the amount of interference that occurs. The hypothesis is that a sensory stream being used for balance maintenance would enhance information processing compared to a sensory stream not required for balance. This was tested by comparing interference between a postural challenge and a visual choice RT (VCRT) and an auditory choice RT (ACRT); (3) Demonstrate that balance recovery would interfere more with an information processing task requiring a choice between two responses versus a task requiring only a single response. This was tested by comparing interference between postural challenge and auditory choice (ACRT) and auditory disjunctive reaction time (ADRT); (4) Demonstrate that sensory and motoric interference would be modulated by the increased preparatory requirements of randomized presentation of two types of balance challenges (platform translation, platform rotation) relative to separate presentation of each.

Methods

Twenty young (mean age 24 ± 2.4 , 10M) and twenty older (mean age 75 ± 3.6 , 10M) healthy adults with no history of vestibular or neurological disorders participated in this study. The age range of our older subjects was 70–81 years. Informed consent was obtained prior to any participation. This study was approved by the Institutional Review Board of the University of Pittsburgh. Participants were screened for normal vestibular function using caloric and rotational testing (Furman & Cass, 1996) and a neurological examination (by J. Furman). Ankle joint proprioceptive sensation was evaluated using an ankle joint position sense protocol (Lord et al. 2003). Plantar foot cutaneous pressure threshold was determined using Semmes – Weinstein monofilaments, with an exclusionary cutoff of 5.07 (Kumar et al., 1991). Further exclusionary criteria were abnormal binocular visual acuity (with corrective lenses) of worse than 20/40 and hearing loss as measured by clinical audiograms. Older subjects were also required to have a Mini Mental State Examination score of greater than 23 to be included in the study.

Instrumentation/Balance and Reaction Tasks

Underfoot perturbations were induced using a posture platform (Equitest, Neurocom, Inc., Clackamas, OR) that provided rotational and/or translational movements of the floor. For the translational perturbations, the magnitude of the translation was 4 cm in the posterior direction, with a maximum velocity of 24 cm/s. The rotational perturbations occurred about the ankle joint in a toes-up direction, with a magnitude of 3.4 degrees and a maximum velocity of 18 degrees/s. The magnitude and velocity of the perturbations were designed carefully such that the ankle angle dynamics were very similar for the translations and rotations. A loosely fitting harness was worn to prevent injury in the case of a fall. The harness did not inhibit movement during the perturbation.

Reaction time tasks were conducted using handheld microswitch buttons pushed in response to either a visual stimulus (a light emitting diode in front of the subject at eye level) or an auditory stimulus (980-Hz tone). The 980-Hz tone was presented through insert headphones. The three RT tasks used were a VCRT task, an ACRT task, and an ADRT task. The VCRT stimulus was a red LED (1 cm diameter) at one of two brightness levels (104 and 25 cd/m²) that was 1m in front of the subject at eye level, requiring a button push in one hand for the brighter target and the other hand for the dimmer target. The ACRT stimuli consisted of two tones at 980 Hz with loudness amplitudes of 71 and 81 dB, requiring a button push in one hand for the louder target and the other hand for the quieter target. The ADRT task (also referred to as a “go/no go” task) had the same stimuli as the auditory CRT task; however, the required response was a button push for one loudness level and no response for the other loudness level. Thus, from a motor selection perspective the CRT tasks had a choice of two motor responses and the DRT task had only one motor response. The loudness and brightness levels were set based upon preliminary studies we conducted to attempt to have equal difficulty of discrimination in each sensory modality. During the auditory tasks, subjects looked straight ahead. Error rates goals on the RT tasks were between 5–10%. They were monitored during training and during the experiment to ensure subjects were executing as quickly as possible, yet not making excessive mistakes. (Wood and Jennings, 1976)

Procedure

The independent variables in this study were perturbation type, perturbation mode, RT task type, and the time interval between the perturbation onset and the RT stimulus (termed the Stimulus Onset Asynchrony or SOA). (Table 1) The SOAs were distributed with 50 ms time intervals between the RT stimulus and platform movement base upon previous results (Redfern, et al. 2002; Muller, et al, 2004) with initiation from –80 ms to 320 ms within each block with platform initiation always at 0 ms (Figure 1). The two negative intervals (–80 and –30 ms) resulted in the RT stimuli occurring before the perturbation, while the others occurred after the perturbation was initiated.

The protocol included a practice day and three experimental days (Figure 1). The practice session included the three RT tasks while the subjects were seated. The subjects then stood on the platform to become acquainted with the perturbations. Finally, the subjects practiced performing the RT tasks during perturbations, but at 0 milliseconds delays. Thus, subjects were fully acquainted with the experimental conditions. Instructions during the practice and experimental days were to respond as fast as possible to the RT stimulus while maintaining balance. Each subject was required to correctly respond to the stimulus in greater than 90% of the practice trials to continue to the data collection phase. The RT tasks were blocked by day, such that each RT task was performed on a separate day. A block of seated RT trials (42 RT stimuli) was conducted at the beginning of each day to establish a baseline of RT. Two standing perturbation blocks without the RT task (one rotation and one translation) were also conducted to obtain baseline perturbation responses (16 perturbation in each condition). The dual-task data collection on each day consisted of three blocks of each perturbation condition (Rotations, Translations, and Mixed) for a total of nine blocks, which were randomized. Each block consisted of 24 perturbations and associated RT stimuli presented at randomized SOA times, along with 4 catch trials. Of these 4 catch trials, 2 were postural

catch trials, in which a postural perturbation occurred but no RT stimulus was presented and 2 were RT catch trials without a perturbation, but with a RT event. These catch trials were included to prevent predictability and increase alertness. Within each block, the nine SOA times between the onset of perturbation and the RT stimulus were randomized. The inter-stimulus time was randomly selected to be between three and six seconds. Three minutes of seated rest was provided between blocks to reduce fatigue.

Data Analysis

Dependent measures in this experiment were the RTs and the latency of postural response. The RTs were calculated as the difference between the onset of the stimulus (auditory or visual) and the activation of the button. The latency of postural response was defined as the time from initiation of the platform movement to initial active postural response estimated by using center of pressure (COP) recordings (see Muller and Redfern (2004) for details). The dual-task cost was found by subtracting the baseline measures taken during a single task from the measures taken during the dual-task trials. This procedure was performed for both the reaction time costs (δRT) and the postural latencies (δTL) on a within-subject basis.

Statistical analyses on the impact of the independent variables on task cost were performed by using repeated measures analysis of variance with subjects nested within age groups. A significance level of $\alpha < .05$ was used throughout the analyses. Analyses first compared baseline/single task postural and information processing performances across age groups, Perturbation Types, and RT tasks. An overall analysis was then performed on the postural latency dual-task cost to test the impact of the information processing tasks on postural control. A second overall analysis was performed on the information processing dual-task costs to assess the impact of the postural tasks on information processing. These analyses provided the necessary error terms for pre-planned comparisons focusing on the initial SOA's during which interference was expected. Preplanned comparisons examined sensory (ACRT vs VCRT) and motoric (ACRT vs ADRT) interference and the modulation of these effects by either type of postural challenge (rotation vs translation) or mode of postural challenge presentation (Mixed vs. Blocked). Results of the overall analyses (which included the last 5 SOA's) are also presented to provide general context for the specific comparisons.

Results

Baseline (tasks performed independently)

Baseline postural latencies (i.e. those collected on the platform without a concurrent RT task) and baseline reaction times (i.e. those collected while seated) were established for the young and older subjects (Table 2). The postural latencies were influenced by the main effects of Perturbation Type ($F(1,38) = 600.8$, partial $\eta^2 = .89$; $p < .0001$), Perturbation Mode ($F(1,38) = 25.2$; $p < .0001$, partial $\eta^2 = .04$) and Age ($F(1,38) = 9.7$; $p < .01$, partial $\eta^2 = .01$). These latencies were faster for the translations compared to the rotations, faster for single compared to mixed, and longer for the older adults compared to the young adults.

Baseline reaction times were slower for the older subjects compared to the young subjects ($F(1,38) = 17.7$; $p < 0.001$, partial $\eta^2 = .13$). Reaction times were also significantly different

between Tasks ($F(2,76) = 40.3$, $p < .0001$, partial $\eta^2 = .61$). Post hoc contrasts indicated the reaction times were slower for the CRT tasks compared to the ADRT task ($p < .0001$) and no significant difference in reaction times between the auditory CRT task and the visual CRT task ($p = .47$).

Overall Postural task cost (dual-task)

Response latency dual-task costs (δTL) were analyzed including the independent variables (Age, RT Task, Perturbation Type, Perturbation Mode, and SOA) for main effects and first order interactions. Significant effects were Perturbation Type ($F(1,38) = 8.1$, $p < .01$, partial $\eta^2 = .12$) and Perturbation Mode ($F(1,38) = 7.1$, $p = .01$, partial $\eta^2 = .10$). SOA timing and Age Group did not have a significant effect on δTL as main effects. There was a significant Age*Task interaction ($F(2,76) = 5.0$, $p = .01$, partial $\eta^2 = .14$) with latencies for older adults not being different across Task conditions and latencies for young subjects being 5 ms greater for the ACRT compared to ADRT and VCRT. Post Hoc analysis for the Perturbation Mode and Perturbation Type conditions indicated that only the Mixed-Rotation perturbation condition resulted in a δTL that was different from zero ($\delta TL = -6.3$ ms (se 1.4)).

Overall Reaction time task cost (dual-task)

A general analysis of the impact of the independent variables (Age, Task, Perturbation Type, Perturbation Mode, and SOA) yielded effects of Age ($F(1,38) = 4.2$, $p = .05$, partial $\eta^2 = .01$), SOA ($F(8,304) = 36.5$, $p < .0001$, partial $\eta^2 = .34$), perturbation mode ($F(1,38) = 7.2$, $p = .01$, partial $\eta^2 = .02$), and interactions Age*SOA ($F(8,304) = 3.0$, $p = .003$, partial $\eta^2 = .03$) and Task*SOA ($F(16,3757) = 2.9$, $p < .0001$, partial $\eta^2 = .05$). (Figure 2) For the older subjects, post-hoc contrasts showed no significant difference among the δRT s for SOAs from -80 to 120 ms. For the young subjects there was no significant difference in δRT s only for SOAs from -80 to 20 ms. Thus, the older adults took longer to initiate a shift attention away from anticipation of the postural perturbation compared to the young subjects.

To address the specific hypotheses of the study, we focused subsequent analyses on the sensory and motor influences in the preparatory phase (SOA's at 80 , -30 and 20 ms) and SOA immediately after initiation of the perturbation (70 ms).

Sensory Modality Analysis—Preplanned tests that examined the influence of sensory modality on reaction times confirmed interference effects between posture and the information processing task in the preparatory phase. These tests examined dual-task cost, δRT , between the ACRT and the VCRT tasks. This analysis addressed the hypothesis that the sensory modality of the information processing task impacts attentional allocation to the postural control system in preparation for a perturbation. Independent variables were sensory modality of the RT Task (ACRT vs VCRT), age group, perturbation type and perturbation mode with first order interactions. Results showed that δRT was significantly longer for ACRTs compared to VCRTs for the preparatory phase ($F(1,38) = 4.8$, $p = .034$, partial $\eta^2 = .23$). However, there was not a Task effect at an SOA of 70 ms ($F(1,38) = 0.1$, $p = .75$) (Figure 3). Neither perturbation type nor age group influenced this sensory channel difference. There was a significant interaction effect in the preparatory phase between Task and Perturbation Mode (significant differences between modes at SOA's -80 through 20 ms ($F(1,157) > 4.3$,

$p < .03$, partial $\eta^2 = .20$). Mixed mode perturbations increased the ACRT δ RTs by 16 ms compared to the single task mode, while VCRT responses were not significantly different between the presentations of single or mixed modes.

Motor Response Analysis—A second set of preplanned analyses investigated our second hypothesis that the motor response selection complexity impacts attentional allocation and switching between the information processing task and postural recovery. Data from the ADRT task and the ACRT task were compared for the SOA's known to induce interference (Figure 3). The impact of Task (ACRT vs ADRT) occurs in the preparation phase and first SOA after the perturbation. In the preparatory phase, the ADRT task resulted in significantly shorter response delays compared to the ACRT task ($F(1,38) = 7.1$, $p = .01$, partial $\eta^2 = .38$). These differences were not significantly altered by age group or perturbation type.

Discussion

This study found that attention allocation occurs in anticipation of a postural perturbation and during initial processing prior to the motoric adjustment to the perturbation. Dual-task interference between information processing and postural challenge was confined to the preparatory phase and ended once the perturbation response was initiated. This was true for young and older adults; however, the older adults required a longer time, approximately 100 ms more, for the interference to resolve, presumably reflecting a shifting of attention more fully to the information processing task. The 100 ms delay of the resolution of attention in the older participants likely corresponds in part to the greater processing required for their adjustment to the postural perturbation together with slowed switching of attentional focus (Grange and Houghton, 2014). The concept of “posture first” (i.e. that postural recovery has the highest priority for attention allocation in dual-task conditions) was confirmed in these experiments, with minimal effects of the information processing task on postural responses. Attention is allocated in anticipation of a perturbation and then focused on the RT task once the response to the perturbation has been initiated. Interference within the preparatory phase was found to have a greater effect on the ACRT responses compared to the VCRT responses. This is consistent with our hypothesis that the sensory stream involved in balance (vision) would enhance information processing compared to a sensory stream not required for balance (audition). The comparison of the ACRT and ADRT responses found less interference on the ADRT, suggesting a specific effect on motoric function. The requirements of balance maintenance interfered differently on information processing tasks with two potential motor responses (ACRT) versus a single response (ADRT). Thus, interference between postural tasks and information processing tasks arises due to the varying requirements for both sensory and motoric processing.

The slower performance on the information processing tasks in the preparatory phase and within 100 ms after the perturbation suggests a reallocation of attentional processes from the information processing task to the postural control system in anticipation of the perturbation. However, once the perturbation was identified and the proper motor response initiated, attention was then reallocated to the information processing task. The rapid shift of attention to the information processing task the central selection of perceptual-motor action for the

balance adjustment once completed permits the shift in allocation to the information processing task. Thus, the ‘bottleneck’ is in the central processing, e.g. Pashler (1998). This result is similar to that found previously by Muller, et al. (2007) who also found the effect almost solely within the first 150 ms after the perturbation. Of course, the emergence of preparatory effects depends on the possibility of preparation. In the current case, events occurred within a window of three to six seconds from each other. Preparing for a balance adjustment was possible with this foreknowledge. In the absence of such knowledge, interference might show a different temporal course as postural adjustments are processed without such preparation.

The attentional allocation to the postural system interfered with the information processing task differently depending upon the sensory modality of the task. Auditory RTs were affected more than the visual RTs, suggesting that there was greater interference on the auditory task compared to the visual task. The importance of vision relative to audition for balance is well established. We interpret our finding as suggesting that when sensory channels can be shared between two tasks (i.e. posture and the VCRT), there is less interference compared to when the sensory channels are not shared (i.e. posture and the ACRT). Prior work establishes that depending on circumstance and the integrity of different senses, postural control shifts the weight placed on different sensory channels (Peterka and Loughin, 2004; Mahboobin, et al, 2005). Our result suggests that such reweighting also occurs when a sensory channel important for a secondary task coincides with a sensory channel important for posture. So, if the postural task and information processing task have congruent sensory requirements, the dual-task cost is less. And, when the sensory requirements are not the same, increased interference is the result.

The finding of changes in response between the ACRT and ADRT tasks showed that the motoric requirements of an information processing task can have an impact on dual-task interference. When the information processing task has only one motor response choice, ADRT, there was less interference compared to two choices, ACRT. In both of these cases, the decision process was the same, determining whether the tone was high or low, but the motor responses were different. The added requirement of two potential motor responses in the ACRT resulted in greater interference. The interference again occurred during preparation and the initial time after the postural perturbation. This timing suggests that the decision uncertainty between which of two motor programs would be required resulted in greater allocation of attention. This decision uncertainty narrowed the bottleneck more than the uncertainty between a single motor program and inhibiting that response as determined by the stimulus presented.

Increasing the complexity of the postural perturbation by mixing the rotational and translational perturbations had a differential effect on the information processing task that depended on the sensory modality of the task. Reaction times increased for both of the auditory tasks but did not change for the visual task. The mixing of postural task prevented the participant from preparing for a single perturbation where a single motoric adjustment to counter the perturbation was required. As in the result for ACRT versus ADRT, the requirement for preparing for and deciding between two rather than a single perceptual-motor adjustment engaged greater attention allocation and narrowed the bottleneck. The

specificity of this result for auditory stimuli reinforces the hypothesis of specific sensory attention. When the perturbation complexity is increased, there is an increased requirement of sensory attention to determine which perturbation is occurring and initiate the proper response. This sensory attention is focused on sensory channels utilized in posture and away from those not involved in posture. The result may further suggest that allocation is primarily required for the detection of the rotational versus translational stimuli as visual input would be minimally required for the motoric adjustment to the differing stimuli.

The finding of a differential impact on audition and vision reinforces prior insight into the sensory processes serving postural control; namely, that postural control is not dependent on a single sensory modality but is responsive to signal integrating modalities. The three senses primarily used in balance (vision, proprioception, and vestibular) are integrated within the brain to form a model of position and motion of the body. This integrated information then determines the next integrated action of the motoric system that will maintain balance. Evidence to date suggests that these central plans for action are limited by attention in the sense that various actions implicit in concurrent active information processing streams are inhibited in the service of selection of a single action plan (integrated bodily adjustment) for execution (Pashler, 1998). Our prior evidence and those of others suggests that maintaining balance receives a high, if not the highest priority, in this attentional selection, i.e. 'posture first' (Muller, et al., 2007). Sensory reweighting can occur when certain sensory signals are deemed unreliable (Mahboobin, et al, 2005; Maurer, et al., 2006; Peterka and Loughlin, 2004). For example, in a dark room there is an increased reliance on proprioception and when standing on foam there is an increased reliance on vision. Such a reweighting appeared to occur when our participants anticipated a visual relative to an auditory signal to react. The enhancement of this effect when the type of perturbation was intermixed is, perhaps, a bit more puzzling. One could anticipate that since the dominant sense required to determine the perturbation direction or type would be proprioception, vision could play a minor role. In fact, one could predict that sensory attention would focus on proprioception at a cost to vision, and an equivalent cost to audition. But this was not the case. Thus, it would appear that allocation to visual cues remains important and in this context postural control impacted all reliable streams relevant to posture. A limitation to our interpretation is the paucity of the visual environment presented to our participants. The central presentation of the LED might have provided a visual anchor to the participant and attention to this anchor (a form reweighting) may have contributed to the current results.

Overall, the study suggests that attention is involved in postural control in a very dynamic way. Dual-task interference was shown in the preparatory phase and during the initial, pre-motoric phase of the postural adjustment to a perturbation, but rapidly shifted to the information processing task. The sensory and motoric components of postural recovery appear to be influenced by attention differently. Sensory attention appears to primarily influence the sensory integration process through channeling appropriate information. Motoric attention is involved in forming and holding possible responses to potential perturbations to regain balance.

There are "real-life" implications of these findings, particularly for older adults or patients with balance disorders. First, sensory requirements of various tasks performed while

maintaining balance or walking can have an impact on postural control. Sensory congruency can improve postural control, while competing sensory requirements can have a potentially negatively impact. For older adults or patients with balance disorders, the effect could be significant. Second, people with reduced sensory attentional capabilities may be at greater risk of imbalance and falls. A previous study noted that older adults with reduced sensory attentional capabilities had reduced balance function under conditions of sensory conflict. (Redfern, et al., 2009)

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Figure 1.

Protocol diagram including the practice day, where participants experienced the platform conditions and RT tasks, and the subsequent experimental days, which were randomized by the three RT tasks. Also note that the conditions or blocks within each experimental day were also randomized within day. The insert shows with arrows the RT stimulus onset times at different Stimulus Onset Asynchronies (SOAs) during the platform perturbation movement.

Figure 2.
The effect of the SOA on dual-task cost reaction times (δRT) for young and older subjects
(Error bars are ± 1 s.e.)

Figure 3.

Dual Task cost reaction times (δRT) for the preparatory period (-80 , -30 , 20) and immediately post preparatory (70 ms). Sensory modality effect is shown through the comparison of ACRT and VCRT responses. Motoric selection complexity effect is shown through the comparison of ACRT and ADRT responses. Data were averaged across subject groups and perturbation types to show this general effect. (Error bars are ± 1 s.e.)

Table 1

Definitions of independent variables used in the experiment

Perturbation Type:
Translation: Posterior movement of the platform
Rotation: Toes-up rotation of the platform
Perturbation Mode:
Single: A block of trials where only one platform perturbation type is used
Mixed: A block of trials where the two perturbation types are randomly interspersed
RT Task:
VCRT: Visual choice reaction time task
ACRT: Auditory choice reaction time task
ADRT: Auditory disjunctive reaction time task
Stimulus Onset Asynchrony (SOA): Time between the onset of the perturbation and the RT stimulus
–80, –30, 20, 70, 120, 170, 220, 270, 320 ms

Baseline postural response latencies and seated reaction times taken prior to dual-task conditions (ms)

Table 2

		Young		Older	
		Rotations	Translations	Rotations	Translations
Latencies (mean (sd))	Single	194 (12)	127 (12)	212 (24)	142 (12)
	Mixed	209 (21)	130 (14)	216 (24)	143 (15)

		Young	Older
Reaction Time (mean (sd))	VCRT	452 (67)	555 (85)
	ACRT	452 (78)	534 (92)
	ADRT	347 (80)	431 (102)