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The Influence of Concurrent Cognitive and MotorTasks on Postural Sway in Adults

Muneera Alghanim
Seton Hall University

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BY

Muneera Alghanim

Dissertation Committee:

Dr. Genevieve Pinto Zipp, Chair
Dr. Mary Ann Clark,
Dr. Susan Simpkins

Approved by the Dissertation Committee:

Genevieve B. Zipp ____________ Date 6-15-2009
Mary Ann Clark ____________ Date 6-15-2009
Susan Simpkins ____________ Date 6/15/09

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DEDICATIONS

I want to dedicate this dissertation to Dr. Saud Al-Obaidi. There is no doubt in my mind that without his continued support and counsel I could not have completed this process.

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ABSTRACT

THE INFLUENCE OF CONCURRENT COGNITIVE AND MOTOR TASKS ON POSTURAL SWAY IN ADULTS

Muneera Alghanim, PT, MS

Seton Hall University
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In every day life activities we often perform two or more tasks simultaneously-dual task performance- (Shumway-Cook, & Woollacott, 2006). Till recently, postural control has been considered to be a highly automatic and reflexive task. On the other hand, resent evidence suggests that the control of posture utilizes attentional demands and that the postural control and the cognitive systems interact under dual task conditions (Baker, 2007). Many inconsistencies regarding the effect of dual tasking on postural performance have been reported in the literature; some studies demonstrated that dual task situations improve standing balance (Morioka, et al., 2005; L Swan, et al., 2004), while others showed the opposite (Dault, et al., 2003; Pellecchia, 2003). The purpose of this study was to examine the influences of concurrent cognitive and motor tasks on postural sway in healthy adults. Forty-seven subjects were asked to stand on a force plate with their shoulders in forward flexion, elbows in extension, and hands in mid position with weights strapped onto each wrist. The subjects were instructed to stand still while looking at a picture, read silently, or

play a videogame. Using Bertec force plate, center of pressure variables were calculated including length of center of pressure (LCOP) and center of pressure velocity (COPV). The results showed that under standing and videogame condition the LCOP was significantly greater compared to the standing and silent reading and standing still conditions. Also the COPV was significantly greater during the standing still condition compared to the standing and silent reading condition. There were no significant differences in COPV under the standing still and standing and videogame conditions. From these results it seems that the type of the task rather its difficulty that influenced the COP measures. The findings of this study support the capacity sharing theory, in terms that when the demands of the postural and concurrent tasks exceed the attentional capacity limits then the performance of either or both decreases. Further studies are needed to investigate the effects of dual tasks, utilizing various cognitive and motor elements, on postural performance in older adults and in individuals with balance impairments.

Chapter I

INTRODUCTION

Many activities of daily living require the coordinated, simultaneous performance of more than one task. This is referred to as dual tasking, concurrent dual tasking, or multitasking (Huxhold, Li, Schmiedeik, & Lindenberger, 2006; Silsupadol, Siu, Shumway-Cook, & Woollacott, 2006). For example standing while conversing with another person, is a common occurrence in every day life requiring the maintenance of an upright posture while cognitively attending to the conversation. Therefore, the successful and safe performance of a sensory-motor task (i.e., standing) simultaneously with a cognitively demanding activity (i.e., talking) utilizes different levels of attention and postural control (Baker, 2007; Blanchard et al., 2005; L Swan, Otani, & Loubert, 2006; Woollacott & Shumway-Cook, 2002).

Postural control is the maintenance of the upright posture for the purposes of balance and orientation and occurs during a specific static posture such as standing, when changing positions, performing voluntary movement, and reacting to external disturbances such as a push or a slip (Blanchard et al., 2005). Historically, researchers have assumed that postural control is a reflexive and highly automated task that occurs in response to sensory and visual information, requiring minimal, if any, cognitive processing or attentional resources (Baker, 2007). A growing body of the literature, however, has provided evidence supporting the notion that postural control requires a significant amount of attention and thus is not solely automatic (Alais, Morrone, & Burr, 2006; Baker, 2007). For example, a person may walk down a quite street while talking on the cell phone with ease but when he/she wants to cross a busy street then he/she might stop talking on the phone to insure safe crossing, or keep talking on the phone and risk their safety. This example shows that the attentional requirement of the same task changed under different external stimuli and how one must choose to attend to the more important task to ensure effective, successful, and safe completion of the multiple tasks at hand.

Attention in human performance is defined as "the conscious and non-conscious engagement in the perceptual, cognitive and/ or motor activities before, during, and after performing a skill; the human information processing system includes limitations in the number of these activities that can be performed simultaneously" (Magill, 2001, p117). Attention manifests in many ways including: arousal, alertness, focused attention and internal/ external distractibility, cognitive speed, sustained attention, vigilance and persistence; working memory and attention span; shifting and dividing attention, performance consistency and ability to mobilize and direct attentional resources (McCulloch, 2007). It is this latter component of attention, the ability to mobilize and direct attentional resources while performing two tasks simultaneously, that has been the focus of the dual tasking postural control literature in the last few years. Thus, dual tasking postural control is the regulation of postural stability, while performing another concurrent task (Huxhold et al., 2006). Dual task paradigms were first developed by cognitive psychologists to examine the interaction between attention and postural control when two tasks are performed simultaneously. In these paradigms, one of the tasks is designated as the primary task or postural activity, while the secondary task is designated as either a cognitive or a motor activity. Measurements of performance of each task separately (single task condition) and concurrently (dual task condition), allow researchers to identify the attentional demands associated with each task when performed separately and simultaneously (O'Shea, Morris, & Iansek, 2002; Redfern, Jennings, Martin, & Furman, 2001; Siu & Woollacott, 2007).

Postural control and stability under static and dynamic conditions have been commonly measured by means of postural sway, which is the displacement of the body's center of gravity (Blanchard et al., 2005; McCulloch, 2007). Postural sway has been shown to be influenced by the concurrent performance of cognitive or motor tasks. The nature of the mutual influence of a cognitive or motor task on the postural task however remains controversial. For example, some studies with young adults (age range 18- 35 yrs) found that performing a cognitive or motor task while standing increased postural sway, i.e., decreased postural stability (Pellecchia, 2003), while others found that it decreased postural sway and improved postural stability (Morioka, Hiyamizu, & Yagi, 2005; L Swan, Otani, Loubert, Sheffert, & Dunbar, 2004).

The interaction between the postural task and the secondary task can interfere with the performance of one or both tasks under dual task conditions. The reduced performance of one or both tasks is referred to as dual task interference. The decrement in performance results from the decrease in attention to focus on simultaneous performance of both tasks (McCulloch, 2007; Woollacott & Shumway-cook, 2002).

Several theories were developed to address the limitations of attention and explain dual task interference. The Filter theory of attention or bottleneck proposes that an individual may have difficulties in dual or multi tasking, due to the fact that an individuals' information-processing system functions in a serial or sequential order, and thus can process only one piece of information at a time (Magill, 2001). This means that somewhere along the stages of information processing, the system filters out the information not selected for further processing (figure 1). Variations of this theory were based on the processing stage in which the bottleneck occurred. It could happen at the stimulus encoding, identification, or decision-response stage. When such sources of interference occur, the nervous system is thought to temporarily postpone operations on one task in favor of operations on the prioritized task, resulting in reduced performance on the non-priority task (Fraizer & Mitra, 2007; Magill, 2001; Pashler, 1994).

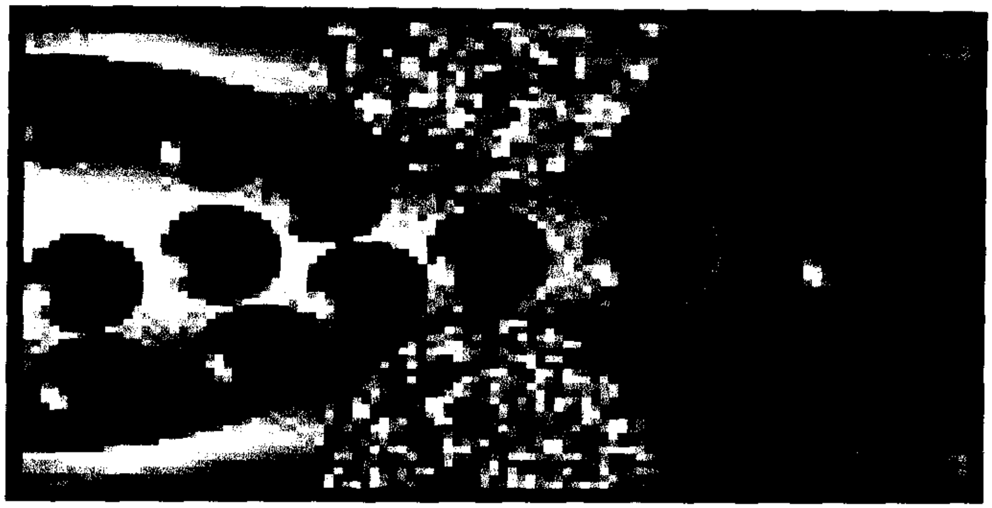

Figure 1. A representation of the filter or bottleneck theory. The attentional capacity filters out unwanted information and process one piece of information at a time. It could take place at the stimulus encoding, identification, or decision-response stages, resulting in dual task interference.

The capacity or resource sharing theory provides an alternative explanation for dual task interference (figure 2). It proposes attentional resources limits. It emphasizes that an individual can perform several tasks simultaneously, as long as the resource capacity limits of the system are not exceeded. However, if these limits are exceeded, difficulties arise when performing one or more tasks simultaneously. This theory suggests allocation of attention may either be from one central resource pool or from multiple sources of resources (Magill, 2001). In this regard, when combined tasks' demands exceed (centralized or particular) resource supply, degraded performance is observed in one task, or both (Fraizer & Mitra, 2007).

In contrast to the capacity sharing theories, selection of action concept provides an action-oriented approach (Pellecchia, 2003). "This approach postulated that attentional mechanisms have evolved to meet functional purposes- to meet the requirement of the goal-directed behavior. The successful execution of an action requires the coupling of relevant sensory information to appropriate effectors. Processes of selective attention are responsible for this linkage of perceptual and motor subsystems. Dual task performance is a special case of selection of action. Every goal- directed action has a range of conditions needed for its successful execution. When conflict between the conditions for two or more intended actions takes place, then one or both must be modified sufficiently to enable their continued execution. Failing that, one activity must be given priority while the other is postponed or abandoned" (Pellecchia, 2003).

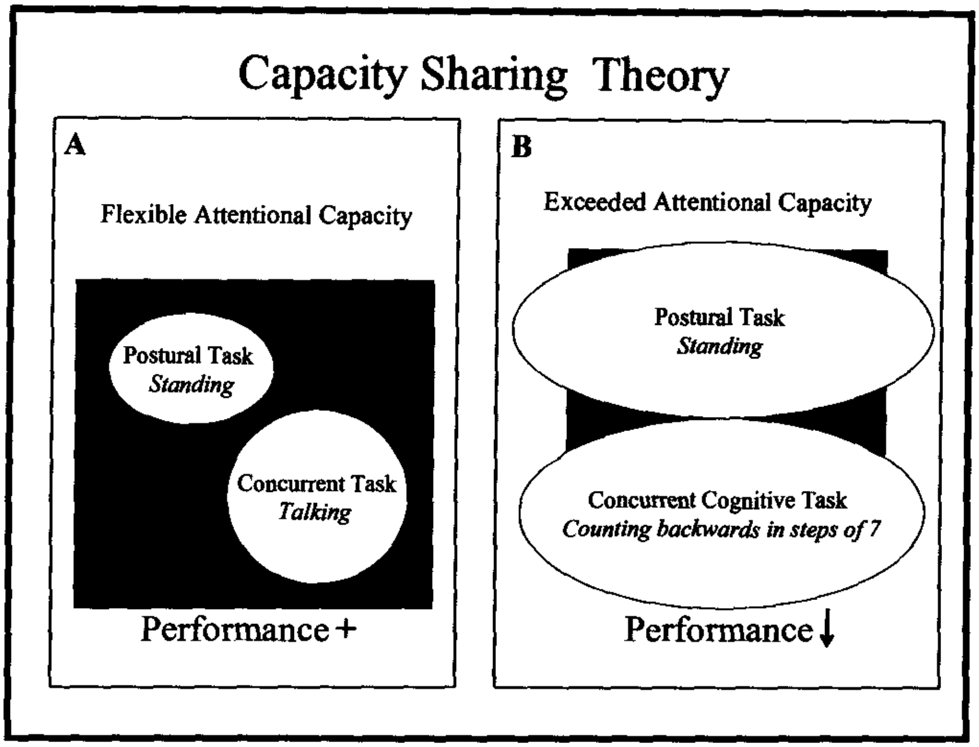

Figure 2. Diagrammatic representation of the capacity sharing theory. Box A: An individual is performing two tasks, standing and talking, simultaneously and successfully because the attentional demands of both tasks did not exceed the limits of the attentional resources capacity. Box B: An individual is performing two tasks, standing and counting backwards in steps of seven. The performance of either or both tasks may deteriorate because the simultaneous performance of both tasks exceeded the limits of the attentional capacity.

There are many inconsistencies in the studies investigating the influence of cognitive or motor tasks on postural sway. These may be due to methodological confounds, the use of postural sway measures that are insufficient or uninformative, and inconsistencies in the secondary tasks selected. For example, some studies have confounded the behaviors involved with cognitive reporting, (e.g., button pressing or speaking) with the cognitive task itself, (e.g., speeded responding or memory tasks) (Baker, 2007). While others have used relatively simple motor tasks that impose a weak postural challenge, (e.g., holding a tray, or coin transference) (Morioka et al., 2005; O'Shea et al., 2002; Voelcker-Rehage & Alberts, 2007). Therefore this study investigated the influences of performing concurrent cognitive and motor tasks, with varying levels of attentional demands, on the performance of postural sway.

Purpose

The purpose of this study was to examine the influences of concurrent cognitive and motor tasks on postural sway in healthy adults.

Research Question

What are the effects of concurrent cognitive and motor tasks on postural sway in adults?

Hypotheses

a) It was hypothesized that postural sway in adults will decrease with the performance of concurrent cognitive and motor tasks.

b) It was hypothesized that tasks requiring more cognitive processing will influence postural sway to a greater degree than those requiring more motor elements.

Chapter II

RELATED LITERATURE

Postural Sway and Center of Pressure

Postural sway has been used as a means to measure postural stability and control under static and dynamic conditions (Blanchard et al., 2005; McCulloch, 2007). Typically it is measured as the spatio-temporal change of center of pressure (COP). Center of pressure (COP) is the average location of the point of force application on the support plane (Baker, 2007). Force plates are typically used to calculate COP variables by measuring the ground reaction forces applied by the person standing on the force plates (Siu & Woollacott, 2007). There are many statistical descriptors of COP such as the length of center of pressure (LCOP)- Euclidean distance traversed in the anterior-posterior and mediolateral planes- the standard deviation, range, speed and velocity of COP (Baker, 2007; Siu & Woollacott, 2007). Elliott, FitzGerald, & Murray, 1998 noted normal values of LCOP in 58 subjects (age range 15-64) to be 140 mm with eyes open, and 200 mm with eyes closed over a 30- second period. Increased values of LCOP descriptors are assumed to reflect decrements in postural control (Riley & Turvey, 2002).

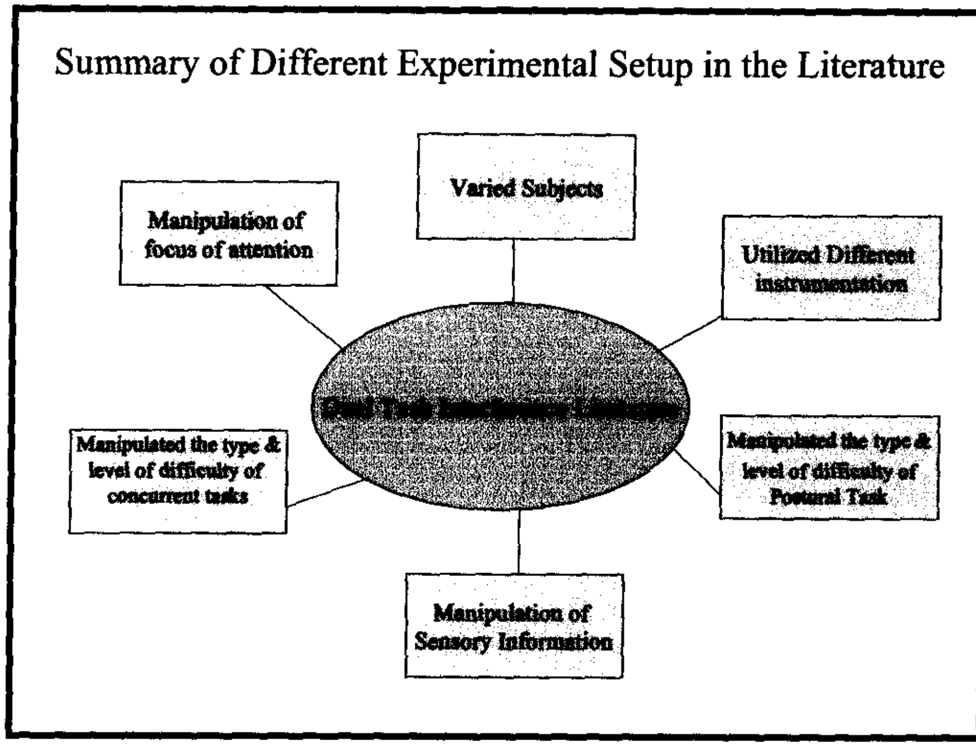

Figure 3. A diagrammatic representation of the different methodological setup in the literature to examine the relationship between postural control and cognition.

Dual Task Performance in Healthy Young and Older Adults

Researchers have examined the interaction between postural control and attention under different conditions including: introduction of postural perturbations, manipulation of the difficulty levels of the cognitive tasks, and directing the focus of attention to the performance of either the postural task or the concurrent task separately or concurrently. Siu & Woollacott, (2007) examined the ability of eleven college students (age range of 20-34 years) to shift attention between a postural and a secondary task. The researchers instructed the participants to either focus their attention on standing alone, or on a visual spatial memory task alone, or to equally focus their attention on the performance of both tasks. The researchers used a custom-built force platform to measure postural variables. Subjects were asked to perform the conditions by standing with feet together for 32 (s) on the platform. LCOP and the average velocity of the COP during each trial were calculated. Verbal response time (VRT) was calculated to measure the performance of the visual memory task. The results showed that VRT significantly improved when the instructions were directed to focus attention only on the visual memory task, while there were no significant changes in the LCOP or the velocity of the COP regardless of the instructions. Moreover, LCOP was significantly reduced under the three instructional sets compared to the baseline condition. It was concluded that young adults have the ability to shift attention in relation to the secondary task but not the postural task suggesting that postural stability is being given a higher priority under dual task conditions.

Morioka et al., (2005) found similar results. They recruited 17 women 19-32 years of age and asked them to stand on a force plate with arms in forward flexion of the shoulders and extension of the elbows under three conditions: grasping a 100 (g) weight in each hand (motor task); holding a tray with both hands with 200 (g) placed on the tray (motor task); and holding a tray with both hands on with a cup filed with water weighing 200 (g) (cognitive task). Two foot positions were used during the tasks: legs closed with the medial margin of the feet in contact with each other, and legs in tandem position. The subjects were tested with and without vision. Postural sway parameters including: LCOP, and sway standard deviation in the anteroposterior and mediolateral direction were calculated using a force plate. Participants were instructed to sway as little as possible in all conditions, and not to spill the water in the tray-water condition. Generally, the results showed that LCOP values were significantly greater under tandem stance with or without vision as compared to feet together. It appears that the decreased base of support made the subjects sway more to maintain balanced. In addition, with eyes open and legs closed, LCOP was significantly reduced during the water-tray condition (cognitive task) as compared to the weights and tray-holding conditions (motor task). In tandem stance with eyes open, LCOP was significantly reduced during the water-tray condition compared to the weights condition only. When comparing postural sway with eyes closed, legs closed, and tandem stance, LCOP was significantly less variable during the water-tray condition compared to the weight-condition only. To summarize, postural sway was reduced significantly under the tray-water condition (cognitive task) compared to carrying weights with hands or on a tray (motor tasks) regardless of the foot position or vision condition. During the motor tasks, holding weights using either the hands or a try the automatic strategy of maintaining the upright posture was selected, regardless of the foot position or the vision condition, and without the conscious control over postural sway. While during the cognitive task, regardless of foot placement and vision condition, it seemed that the consistent monitoring of the water in the glass to prevent spilling while standing resulted in reduced postural sway measures. Thus it could be inferred from these results that the task that had higher cognitive demands reduced postural sway more than the tasks that had higher motor demands.

Swan et al., (2006) examined 98 women (ages 18-27 years) under two levels of difficulty of the cognitive activity (easy, difficult) using the Brook's tasks with spatial and nonsense sentences. For the easy cognitive tasks subjects were asked to respond to an audio stimulus when cued and place numbers or sentences in ascending order in 4X4 grid, whereas for the difficult cognitive tasks the numbers or sentences were random. For the postural task three levels of difficulty were designated: standing with feet together (easy), standing with feet together with applied vibratory stimulations to the bilateral gastrocnemius muscles (medium), and tandem stance (difficult). All participants were tested blindfolded (to reduce the effect of visual inputs as the experimental procedures utilized visual feedback after the responses of the subject were given) with arms crossed over their chests in all conditions. The researchers used the Balance Master to calculate the COP measures. They reported the time spent in balance correction (TSBC) as their measure instead of using the COP length or its standard deviations. Their findings showed that under dual task conditions, only the difficult cognitive tasks had significant effects on decreasing postural sway scores (i.e., increasing postural stability) and that the most difficult postural task had no significant effects on the postural performance.

Andersson, Hagman, Talianzadeh, Svedberg, & Larson, (2002) induced postural perturbations by stimulating the calf muscles in 50 young adults while they counted silently backwards in steps of seven in experiment one (n = 30, mean age 27.4 years). In the second experiment the similar procedures were used but the subjects (n =20, mean age 30.1 years) were asked to focus their attention either on the accuracy of counting or the balance task. Postural sway in the anteroposterior and mediolateral directions was calculated, as well as the accurate responses of counting. The researchers found that balance perturbations led to decreased performance of the cognitive task in experiment 1 but not in experiment 2; where the focus of attention on the accurate performance of the cognitive task was augmented. They also found that instructions to focus attention on the balance task had little or no effect on balance performance. In both experiments subjects swayed less under dual task conditions compared to the single task condition (counting while standing with or without calf stimulation) and the effect was attenuated when attention was focused on the accuracy of the cognitive task performance.

Pellecchia, (2003), in an earlier study, found contrasting results. The researcher instructed 20 participants (ages18-30 years) to stand still on a foam surface placed over the force plate during the single task condition. For the dual task conditions the level of difficulty of the cognitive task was manipulated. The cognitive tasks included; digit reversal (easy), digit classification (moderate), and counting backwards in 3s from random numbers (difficult). LCOP, sway range and variability in the anteroposterior (AP) and mediolateral (ML) directions were calculated using an AMTI force plate. The results showed that LCOP, AP and ML sway range, and AP sway variability measures were significantly greater for the counting backwards condition compared to the other three conditions. Concluding that as the attentional demands of the cognitive task increased, postural sway measures also increased (i.e., decreased postural stability). The findings of Mitra & Fraizer, (2004) and Dault, Yardley, & Frank, (2003) support those of Pellecchia, (2003) in that as the cognitive load of the concurrent task increased so did the amount postural sway.

Others examined age-related changes associated with postural control and cognition under dual task conditions. Prado, Stoffregen, & Duarte, (2007) investigated postural sway changes during dual task conditions in 12 elderly adults (ages 65-75 years) and 12 young adults (ages 22-39 years). Postural sway was measured during standing with eyes open and eyes closed examining age related changes concerning vision and postural sway. The dual task conditions included two visual tasks: inspection vs. search at two target distances, near vs. far. COP displacements and speed in the mediolateral (ML) and anteroposterior directions

(AP), and body movement was measured. The results showed that under single task condition elderly subjects swayed more than young adults under both conditions but even more so with eyes closed. The elderly subjects also had significantly higher COP speed in the ML and AP directions as well as significantly higher head displacement when compared to the younger adult group under eyes open and eyes closed conditions. Under dual task conditions, older age group had significantly more COP displacement and greater speed in both AP and ML directions and also performed with less accuracy regarding the visual task compared to the younger age group.

Huxhold et al., (2006) examined dual task effects on postural control related to age and cognitive demand in 20 young adults (mean age 24.5 years) and 19 older adults (mean age 69.8 years). They hypothesized that under dual task conditions with low cognitive demands, postural control would improve, but as the cognitive load increased, decrements in postural control would occur, and these effects would be more apparent in older age group than the younger one. Five conditions were utilized: standing (single task condition), standing while watching digits displayed on a screen, standing while performing a choice reaction time task, standing while performing a visual working memory task, and standing while performing a spatial memory task. The dependent variables included accuracy of the cognitive task, and time spent performing the reaction time task. For the postural control variable the area of COP excursions was calculated. Results indicated that COP excursions decreased in both age groups under dual task conditions compared to single task condition. However, when performing more attentionally demanding cognitive tasks, older adults showed increased postural sway whereas the young adults did not. As for the cognitive tasks the accuracy of the cognitive performance was less and the reaction time was longer in the older age group when compared to the younger age group.

In summary, multiple studies suggest that under dual task conditions, the most critical factor impacting postural control is the level of difficulty of the concurrent cognitive tasks and not the level of difficulty of the postural tasks. Instructions to focus attention on standing posture under single and dual task conditions have detrimental effects on postural control in healthy adults. Huxhold et al., (2006) proposed a model of a U-shape interaction between postural control and cognitive demands of the secondary task. They explained the descending part of the U-shape interaction as the beneficial range of the concurrent task; for low cognitive demands, concurrent cognitive activities improve postural performance by shifting the focus of overt attention away from a highly automatic postural activity. In other words, focusing attention on a highly automatic behavior such as the control of posture interferes and reduces the efficacy of this automatic process. While the external focus of attention provided by the low cognitive demands of concurrent tasks enables the postural control system to self-organize automatically and thus improves postural stability. While the ascending part of the U-shape interaction reflects where the dual task interference is shown; the high cognitive demands of the concurrent task reduce postural control. The negative effects of the resource competition of the high cognitive demands of the concurrent tasks exceeded the benefits of the low cognitive demands of the concurrent task in enhancing postural control (external focus of attention), and thus decreasing postural stability under dual task conditions.

When comparing elderly adults with young adults under single task conditions, older adults swayed more than younger adults. Under dual task conditions older age groups swayed more and had less accurate cognitive performance of the concurrent tasks compared to younger age groups. With aging, attentional demands to perform automatic tasks, such as the control of posture, are increased to compensate for the deterioration in the visual, auditory, and sensory/motor systems during quiet standing, and that under dual task conditions, these attentional demands are challenged to a greater extent resulting in a decline in postural stability (Woollacott & Shumway-cook, 2002; Yentes, Perell, Fang, & Barr, 2007).

Table 1. Summary of the published studies that examined the influence of the concurrent tasks on postural performance in healthy young adults

Reference	Subjects n (age in years)	Postural task	Concurrent task	Dependent variables	Results
Siu & Woollacott, 2007	11 (20-34)	-Standing	-Visual memory task	-LCOP -COP velocity	LCOP decreased under dual task conditions
Morioka et al. 2005	17 (19-32)	- Standing feet together with/without vision - Standing in tandem stance with/without vision	- Holding weights with hands - Holding weights on a tray - Holding a cup of water on a tray	-LCOP -SD of COP	-LCOP increased under tandem stance - LCOP decreased most under water-tray condition
Swan et al. 2006	98 (18-27)	- Standing feet together -Standing & leg muscles stimulation - Standing in tandem stance	- Easy Brook's task -Difficult Brook's task	-Time spent in balance correction (TSBC)	-Postural sway decreased under dual task difficult concurrent tasks only
Anderson et al., 2002	30 in experiment 1 (mean 27.4) 20 in experiment 2 (mean 30.1)	- Standing - Standing with leg muscles stimulations	- Counting backwards in steps of 7 with instruction to focus of attention on postural &/or cognitive task	-COP in AP & ML direction	-Instructions did not benefit balance performance -Less sway under dual task conditions
Pellecchia (2003)	20 (18-30)	- Standing on a compliant surface placed over the force plate	- Digit reversal - Digit classification -Counting backwards in 3s	-LCOP - Sway range in AP &ML directions -Sway variability in AP& ML directions	All dependent variables were greater under the counting backwards condition; the most difficult

Dual Task Performance in Adults with Balance Impairments

Redfern, Talkowski, Jennings, & Furman, (2004) investigated the interference between postural control and cognitive processing in 15 patients with unilateral vestibular loss (mean age 48.5 years) and 15 age and gender matched controls (mean age 48.7 years). The researchers varied the level of difficulty of the postural and the cognitive tasks. Postural stability was assessed under four conditions: seated, standing on a fixed floor, standing on a sway-referenced floor, and standing on a translating floor. The complexity of the cognitive task was varied using: an auditory simple reaction time task, an auditory choice reaction time task, and an inhibitory reaction time task. Postural sway including COP displacements in the anteroposterior direction (AP) and COP velocity, reaction times were measured. The result showed that the patient group with unilateral vestibular loss had slower reaction times for the cognitive tasks when compared to the control group not only for the standing conditions but also for the seated condition. Regarding postural sway measures, results showed that as the postural task increased in difficulty, postural sway increased similarly in both groups, with the vestibular group swaying more. The authors concluded that subjects with unilateral vestibular lesion require increased attention compared to healthy controls and that increased attentional demands extend beyond postural control to compensate for spatial orientation, vestibulo-ocular components. They also proposed that dual task interference may be at the sensory integration level for resolving multiple sensory signals for spatial orientation which further supports the bottleneck theory.

Contrary to the findings of Redfern et al., (2004) were those of Yardley et al., (2001) who examined the interference of postural control and cognitive tasks in 48 adults with vestibular disorders (mean age 44.65 years) and 24 healthy adults (mean age 44.25 years). They assessed postural sway while subjects were standing with eyes closed on a stable and a moving platform. The cognitive activities were comprised of low spatial, low non-spatial, high spatial and high non-spatial tasks. Postural sway, amplitude and velocity of COP, accuracy and reaction time of the cognitive tasks were calculated. The effect of the challenged postural task (moving platform) included longer reaction times and more inaccurate responses especially when performing non-spatial tasks for the vestibular group compared to the control. As for the postural sway measures, even though vestibular patients had higher sway (lower postural stability) compared to the control group, no significant effects of the cognitive task on the performance of the postural task was found between the patient and control groups. In other words, the levels of dual task interference between postural control and cognitive activity were similar in patients with vestibular disorder and healthy controls. These finding give support to capacity sharing theory; when the performance of both tasks (postural and cognitive) exceeds the available information processing capacity, then the performance of one or both tasks deteriorates.

Brauer, Broome, Stone, Clewett, & Herzig, (2004) suggested that dual task interference is unlikely to be due to structural interference or a reduced attentional capacity of subjects with acquired brain injury (ABI). The researchers examined the interference associated with performing a balance task while concurrently completing five cognitive tasks varying in visuo-spatial attentional load and complexity. Subjects included 20 adults with ABI, with age range of 18-57 years, and 20 age, sex, and education level matched controls. The cognitive activities included simple and complex auditory, visuo-spatial, and a control articulation tasks (five total), all of which were performed while the participants were in step stance. Total distance, velocity, amplitude, and frequency of COP and reaction time of the cognitive tasks were calculated. Subjects with ABI demonstrated greater COP excursion and velocity than the control participants but no difference in amplitude or frequency of COP motion under single task condition. In addition, the type of the task (spatial vs. non-spatial) rather than task complexity (easy vs. difficult) appeared to have the greater impact on dual task interference in adults with ABI. When non- spatial and visuo-spatial tasks were compared, the non-spatial tasks showed greater interference, particularly in adults with ABI, suggesting that changes in postural performance were not due to structural interference. A critical limitation in this experimental setup may have confounded the results. Under single task conditions all participants stood in a step stance position while holding onto a rail for support, while under the dual task conditions they stood in a step stance without external support while performing spatial and non-spatial tasks. Thus standing and holding onto a rail provided unneeded external support and sensory-motor information for all participants particularly the control group, consequently resulting in faulty baseline measures.

Alzheimer's disease (AD) is associated with cognitive deficits and posture and balance disturbances that are more severe than those observed in normal aging adults including increased postural sway. Manckoundina, Pfitzenmeyer, Athis, Dubost, & Mourey, (2006) examined the effects of performing a cognitive task while standing in 13 patients with AD (mean age 79.7 years) and 17 healthy elderly (mean age 78.5 years). Standing still, on a force plate, was the single task condition. Standing while answering questions about a videotape watched prior to data collection was the dual task condition. COP area and path length were calculated. Patients with AD had significantly higher COP area and COP path under single and dual task conditions compared to the control group. Surprisingly the healthy elderly group had no significant changes in COP measures under single or dual task conditions. A limitation of this study is that the researchers captured data for only 13 seconds for single and dual task conditions. They also instructed the subjects to stand on the force plate with arms crossed at the chest. The data collection time and the arm position may have confounded the results, especially those pertaining to the healthy elderly group as the test period was relatively short, compared to 30 seconds of data collection evident in the literature and maybe not enough to induce any changes in COP measures in the healthy elderly group. The arms were crossed in front of the subjects, compared to arms by the side of the trunk, which may have caused anterior translation of the COP, thus offsetting postural sway measures especially in the anterior-posterior direction. Thus, these results can not be generalized to other healthy older adults.

Dual task interference was also examined in patients with Parkinson's disease (PD) during standing and locomotion. Marchese, Bove, & Abbruzzese, (2003) instructed 24 patients with PD (mean age 66.4years) and 20 healthy subjects (mean age 60.9 years) to stand still, stand while counting backward aloud in multiples of three, and stand while performing thumb opposition keeping both arms by their sides. Testing was conducted with eyes open and eyes closed for all the conditions. COP area and path were calculated. Under single task condition, there were no significant differences between the COP area and path between patients with PD compared and healthy subjects, with either eyes open or eyes closed. Under dual task conditions, patients with PD had significantly higher COP area compared to healthy controls. Also patients with PD swayed more compared to the healthy controls but this difference did not reach significance. Similar observations were reported by Bloem, Grimbergen, Dijk, & Munneke, (2006); Morris, Iansek, Smithson, & Huxham, (2000). The former group of authors suggested that the subjects with PD adapted "posture second" strategy. In contrast, healthy young and elderly adults adopt the "posture first" strategy. In this strategy healthy subjects correctly perceived the difficulty and the importance of the multiple tasks at hand and purposely choose to execute the more important task, that is to keep a stable posture during standing, or to prevent falling during walking at the expense of the performance of the other concurrent task. On the other hand, PD patients' ability to prioritize allocation of attention to the postural task is impaired therefore they treat all tasks with equal priority regardless of their complexity. The individuals with PD may choose to perform the secondary task at the expense of the postural task resulting in deterioration of balance, hence the term "posture second" strategy.

In general, many studies using dual task methodology with young healthy subjects have shown increases in postural sway measures (i.e., decreases in postural stability) when the performance of a postural task is paired with the performance of a cognitive task (Dault, Frank, & Allard, 2001; Dault et al., 2003; Mitra & Fraizer, 2004; Pellecchia, 2003). Also, decrements in cognitive performance in response to challenged postures have been repeatedly documented (Dault et al., 2003; V Ramenzoni, Riley, Shockley, & Chiu, 2005). On the other hand, some studies have shown improvements in postural stability under dual task conditions especially when utilizing difficult cognitive tasks (Dault et al., 2001; Yardley et al., 2001).

Still other studies reported inconclusive results when examining the relationship between postural control and cognition in regard to postural sway measures. Alais et al., (2006) found that performance of concurrent cognitive tasks increased sway frequency, but decreased sway amplitude, relative to the single task condition. The effects of the performance of a cognitive task on postural control also seemed to depend on the characteristics of the secondary cognitive task. (Mitra &

Fraizer, 2004) also reported that postural sway measures and dynamics were differentially affected depending on the nature of the concurrent cognitive task performed, (i.e., visual vs. verbal, and encoding vs. retrieval).

The results reported regarding dual task interference in healthy adults and patients with balance impairments are inconsistent. These inconsistencies can be due to methodological confounds regarding the variations in the concurrent tasks selected and the use of postural sway measures that are insufficient or uninformative.

Methodological confounds may arise from differences in task demands and instructional set regarding the focus of attention. Many of the cognitive dual tasks mentioned above required a verbal or manual response, or a visual fixation. For example, Brooks' spatial matrix task frequently employed to test for spatial cognitive interference in posture control could be performed using verbalization of the sequence of directions for the spatial activity; it is the verbalized responses that could act as a direct source of interference. A further complicating factor is that some experimental designs have used tasks that center on spatial attentional processes, such as speed of visual processing (Shumway-Cook & Woollacott, 2000), while others have used tasks designed to tap memory functions, such as retention and recall tasks (Ramenzoni, Riley, Shockley, & Chiu, 2007; Riley, Baker, & Schmit, 2003). While attention and memory are thought to be functionally linked, the precise attentional demands and characteristics of these processes are not fully understood. Another issue regarding interaction between postural and cognitive tasks is whether the concurrent task is more demanding on cognitive or perceptual resources. Researchers interested in 'pure' cognitive load effects on postural control have minimized the perceptual as well as motor content of secondary tasks (Fraizer & Mitra, 2007).

Another methodological confound that could interferer with postural performance arises from the different instructions given to the participants during single and dual-task conditions. Previous studies differ in the emphasis given to the posture task; participants in some studies were instructed to stand normally or relaxed (Maylor, Allison, & Wing, 2001), without cuing or giving any specifications on how to stand, while in other studies specific instructions to minimize sway were given (Dault et al., 2001). These instructions vary in how they draw attention towards the postural task or away from it, resulting in confounding effects on the postural performance.

A major difficulty in interpreting dual-task findings extends from the use of different postural sway descriptors. Postural sway is very difficult to quantify and interpret. Postural data are recorded using force platforms taking the vertical ground reaction forces around the center of pressure COP along the anterior-posterior, or AP, and medio-lateral, or ML directions (Fraizer & Mitra, 2007). It is assumed that parameters calculated from the postural sway signal reliably represent the activity of the postural control system. However, due to the complexity of the information packed in the postural sway signal, its interpretation is complex and may vary according to the statistical parameters chosen for quantification (Fraizer & Mitra, 2007; Riley, Baker, Schmit, & Weaver, 2005). Spectral analysis in the frequency domain has been used to identify postural constraints in terms of time-dependent postural behavior. In the time domain, velocity-related measures (such as COP path length, a measure used in the present study) have been reported to be more accurate in discriminating between decreased balance control and random postural activity compared to displacement-related measures. On the other hand, displacement measures (such as COP standard deviations, which were also employed in the present study) are more informative and take on greater significance when comparing sway performances in different age groups, especially under perturbed stance conditions. There is no agreement, however, as to which summary measure best describes postural stability.

Interpretations of the results could be another source of conflict in these studies. The increased postural sway due to increased cognitive task load should not be automatically considered as postural destabilization; rather it could be interpreted as postural operations that facilitate the acquisition of perceptual information for the supra-postural task (i.e., coordination-based activity) (Fraizer & Mitra, 2007). Similarly a decrease in sway amplitude (or increased sway frequency) in response to added cognitive load cannot be reliably interpreted as an action to protect posture. The postural control system should always be regarded as a dynamic system that is affected by and responsive to the environmental inputs surrounding the individual who is dual tasking thus interpretations should be kept in context.

Chapter III

METHODS

Participants

Fifty seven potential participants volunteered for this study. Four participants were excluded because of past injuries affecting their ankles (2 people) or knee surgeries (2 people). The data of six subjects were excluded from the analysis due to some missing or corrupted data files. Data of the remaining 47 participants were included in the analysis. Thirty females and 17 males (mean age = 25.23 yrs, range = 20-39 yrs) participated in this study. Participants' heights ranged from 1.50 m to1.89 m (mean height = 1.68 m) and weight ranged from 48 to 113.4 kg (mean weight = 70.16 kg). All participants were free from any condition affecting their gait or standing balance, had no range of motion restrictions at the ankle, and had normal or corrected to normal vision. None of the participants had a history of orthopedic or neurological disease, dizziness, balance disorders, falls, or was using medications that may affect standing balance.

Experimental procedures were approved by the Seton Hall University Institutional Review Board, and all participants signed an informed consent prior to participation in the experiment. Each participant was tested individually in a laboratory setting.

Instrumentation

A Bertec Force Plate® FP 4060-08 was used to measure the dependent variables of postural sway including, length of center of pressure, sway range and variability in the mediolateral and anteroposterior directions, and center of pressure velocity. The applied forces were captured in three dimensions and fed to a desk top computer. Data from the force plate were acquired and processed using the Qualisys Track Manager and then analyzed in the Visual3D™, C-Motion, Inc. The reliability and validity of the Bertec Force Plate® was established to be moderate to high with an ICC of 0.80 (Spradley, Goggin, & Jackson, 1996).

Cognitive and Motor Tasks (Independent Variables)

The tasks adopted in this study were similar to daily real life activities and were classified from low to high according to their cognitive and motor demands. The first task standing still (SS) was considered as the baseline single-task condition. This task had relatively low cognitive and low motor demands. The second task was standing while reading (SR). Specifically, the person had to view the text, read silently, understand and retain the information in the text for later questioning while standing still. Based upon the more in depth processing of this task it was considered as a task possing moderately high in cognitive demands and low in motor demands. The third task was standing and playing a videogame (SG). In this task the person had to maintain standing still while playing a videogame. This task required high ongoing cognitive processing of the game, anticipation of the appropriate responses to stay in the game, and the production of the appropriate motor responses to push the correct buttons on the gameboy™ system. Based upon the task demands this task was categorized as having high cognitive and high motor demands.

Procedures

All participants were asked to remove their shoes and socks upon arrival to the lab. Their heights and weights were measured. One 15 second practice trial was administered prior to data collection for each task tested:

1. Standing still
2. Standing while reading silently
3. Standing while manipulating a handheld gameboy™ system

The practice took place on level ground at the Functional Human Performance Laboratory (FHPL) located in Corrigan Hall at Seton Hall University, South Orange, NJ. After the practice trials the subject stood on the force platform for data collection. The order of presentation of the three tasks was randomly assigned to control for order effects. Each subject performed three 30-second trials of each task. The same instructions were given during the practice and experimental trials except during the practice trials the subjects stood on the floor instead of the force platform.

During the experimental trial performance for all tasks the subject was asked to stand on the force plate with the shoulders in 90° of forward flexion, elbows in 0° of extension and the forearms in mid-position. Wrist weights were strapped onto each wrist (100g on each wrist) to deliberately reduce the mediolateral sway and put the subjects closer to the anterior limits of their stability. Feet were positioned approximately 0.10 m apart on the force plate.

For the standing still task, subjects were asked to stand on the force plate while looking at an image of a school placed on a screen 0.60 m away in front in of them at an appropriate eye level. Subjects were instructed to stand still and try not to move.

For the standing while reading silently task, subjects were asked to stand and read an eighth grade level paragraph, placed on a screen 0.60 m away in front of them at an appropriate eye level in a 36 point times new roman font. To insure that the subjects read the text, they were told that they would be asked questions about the content at the end of the testing session. Subjects were instructed to stand still while they read silently.

For the standing and manipulation of a handheld gameboy™ system task, the subjects were asked to and play a Sonic™ videogame. Subjects were asked to stand still and play the game.

An audible computer generated beep was produced at the beginning and at the end of each trial. Subjects were asked to start performing the tasks after hearing the first beep and stop after hearing the second beep.

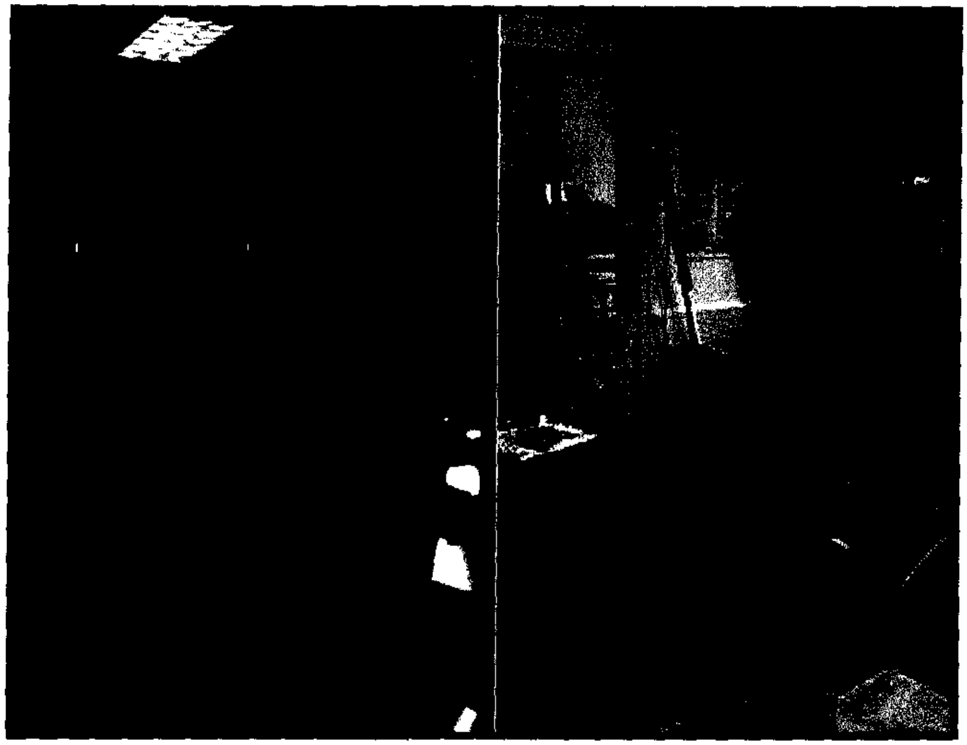

Figure 4. Subject is standing while looking at a school picture (on right) and standing while playing a videogame (on left). The subject's shoulders were in 90° of forward flexion, elbows in 0° of extension and the forearms in mid-position with wrist weights strapped onto each wrist (100g on each wrist).

Study Design

This study utilized a within-subjects repeated measures design.

Statistical Analysis

The independent variables were the three tasks; standing still (SS), standing while reading silently (SR), and standing while playing a videogame (SG). The dependent variables were the length of center of pressure (LCOP), mediolateral sway range (MLSR), anteroposterior sway range (APSR), mediolateral sway variability (MLSV), anteroposterior sway variability (APSV), and center of pressure velocity (COPV). All the dependent measures were calculated via Visual3D™, C-Motion, Inc.

A separate 1x3 (1trialx 3tasks) repeated measures analysis of variance was used to compare the effects of the three tasks and the mean of the three trials on each of the dependent measures. The assumption of sphericity was checked using Mauchly's test, and the Benferroni method was used to perform pairwise comparisons following a significant overall test result. The level of statistical significance was set at $p = 0.05$.

Chapter IV

RESULTS

Effects of concurrent tasks on LCOP

The results for length of center of pressure (LCOP) showed that Mauchly's test of sphericity was not violated (see Appendix E). The overall test for differences in means in the repeated-measures ANOVA was significant, $F\,(2, 104) = 20.32, p =$ 0.029. Pairwise comparisons indicated that at the overall 0.05 level, under the conditions of standing and videogame (SG) ($M = 0.324$, $SE = 0.018$) LCOP was greater compared to the standing and silent reading (SR) ($M = 0.288$, $SE = 0.017$) and standing still (SS) ($M = 0.284$ $SE = 0.016$) (figure 5).

Effects of concurrent tasks on Mediolateral Sway Range (MLSR)

The results for mediolateral sway range (MLSR) showed that Mauchly's test of sphericity was not violated (see Appendix E). The overall test for differences in means in the repeated-measures ANOVA was not significant $F\,(2, 104) = 1.29, p =$ 0.277. Pairwise comparisons indicated no significant differences when comparing standing still (SS) ($M = 0.013$, $SE = 0.002$), standing and silent reading (SR) ($M =$ 0.010, $SE = 0.001$) and standing and videogame (SG) ($M = 0.014$, $SE = 0.002$) conditions.

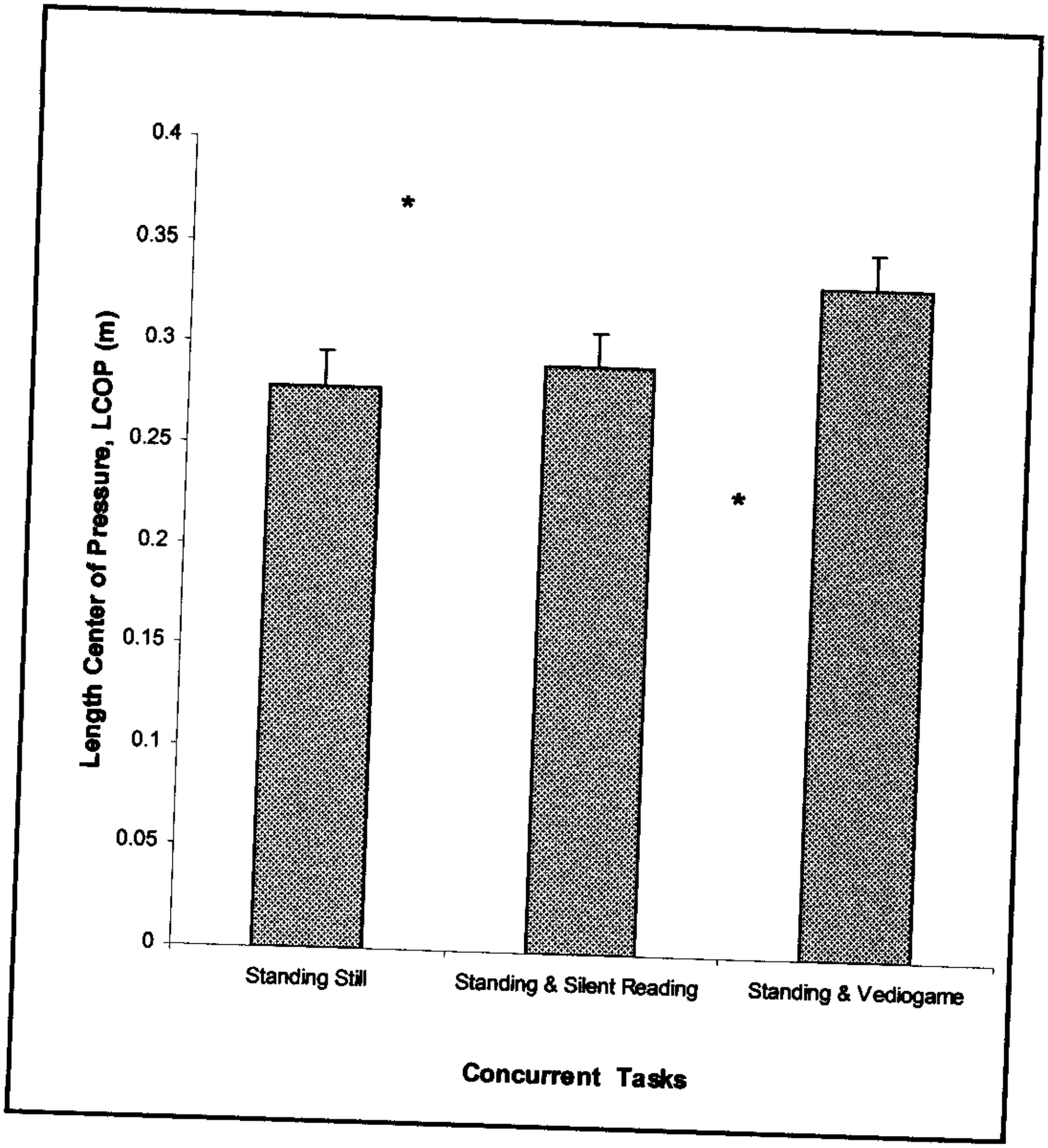

Figure 5. Length of center of pressure (LCOP) in meters as a function of concurrent tasks, * indicates significant level at p= 0.05.

Effects of concurrent tasks on Anteroposterior Sway Range (APSR)

The results for anteroposterior sway range (APSR) showed that Mauchly's test of sphericity was not violated (see Appendix E). The overall test for differences in means in the repeated-measures ANOVA was not significant $F(2, 104) = 1.89, p = 0.16$. Pairwise comparisons indicated no significant differences when comparing standing still (SS) (M =0.022, SE = 0.003), standing and silent reading (SR) (M = 0.018, SE= 0.001) and standing and videogame (SG) (M = 0.022, SE = 0.002) conditions.

Effects of concurrent tasks on Mediolateral Sway Variability (MLSV)

The results for mediolateral sway variability (MLSV) showed that Mauchly's test of sphericity was not violated (see Appendix E). The overall test for differences in means in the repeated-measures ANOVA was not significant $F(2, 104) = 2.21, p = 0.11$. Pairwise comparisons indicated no significant differences when comparing standing still (SS) (M = 0.050, SE = 0.007), standing and silent reading (SR) (M = 0.051, SE = 0.007) and standing and videogame (SG) (M = 0.062, SE = 0.007) conditions.

Effects of concurrent tasks on Anteroposterior Sway Variability (APSV)

The results for anteroposterior sway variability (APSV) showed that Mauchly's test of sphericity was not violated (see Appendix E). The overall test for differences in means in the repeated-measures ANOVA was not significant $F(2, 104) = 1.78, p = 0.17$. Pairwise comparisons indicated no significant differences when comparing standing still (SS) ($M = 0.169$, $SE = 0.021$), standing and silent reading (SR) ($M = 0.139$, $SE = 0.015$) and standing and videogame (SG) ($M = 0.175$, $SE = 0.017$) conditions.

Effects of concurrent tasks on Center of pressure Velocity (COPV)

The results for center of pressure velocity (COPV) showed that Mauchly's test of sphericity was not violated (see Appendix E). The overall test for differences in means in the repeated-measures ANOVA was significant $F(2, 104) = 1.78, p = 0.017$. Pairwise comparisons indicated that at the overall 0.05 level that under the conditions of standing still (SS) ($M = 1.681$, $SE = 0.162$) COPV was greater compared to the standing and silent reading (SR) ($M = 1.260$, $SE = 0.131$). No significant effect on COPV were found when comparing standing and videogame (SG) ($M = 1.631$, $SE = 0.181$), to standing still (SS) ($M = 1.681$, $SE = 0.162$) and to standing and reading (SR) ($M = 1.260$, $SE = 0.131$) conditions (figure 6).

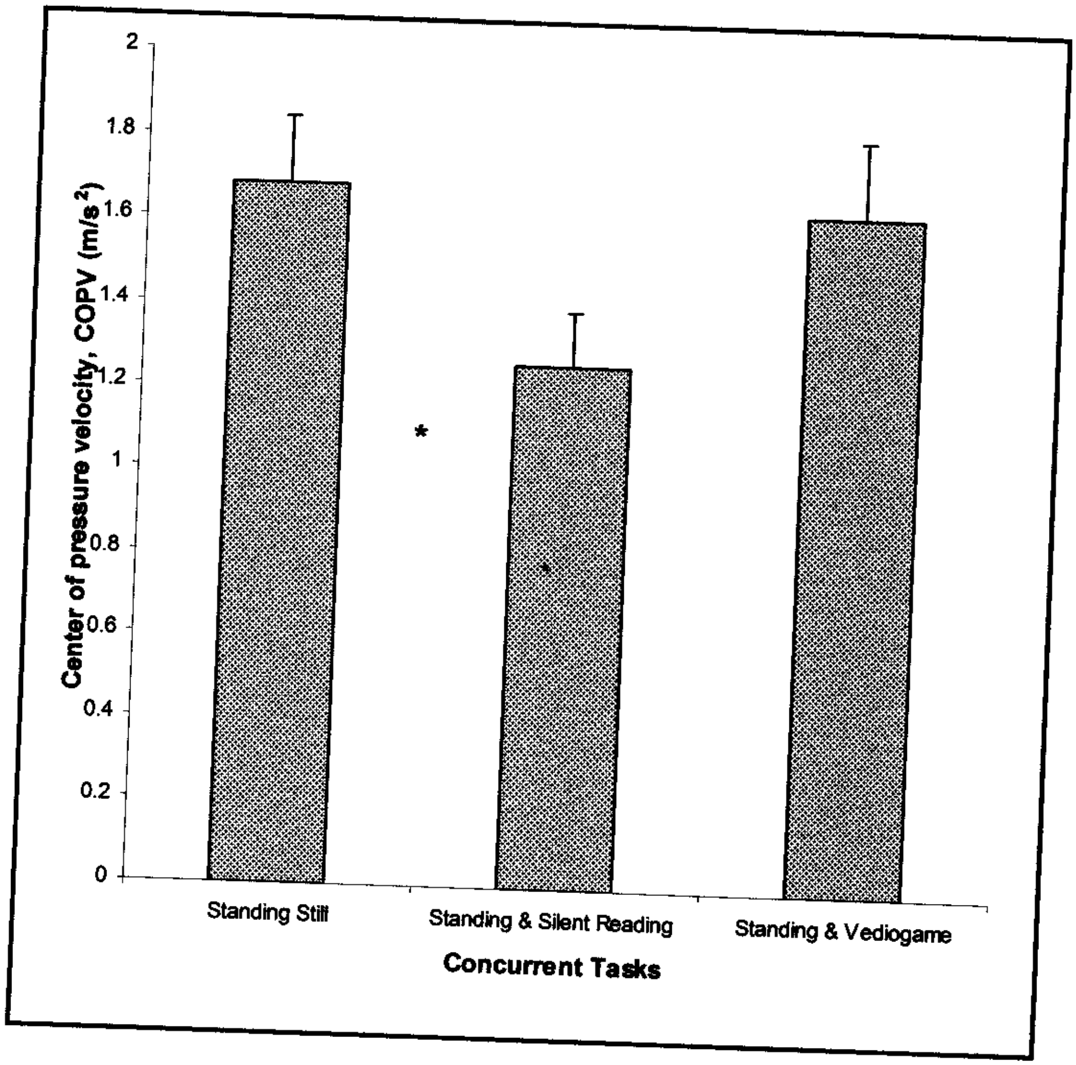

Figure 6. Center of pressure velocity (COPV) in meters/ second^2 as a function of concurrent tasks. * indicates significant level at $p= 0.05$.

Chapter V

DISCUSSION

In this project postural performance under dual task conditions was examined. The cognitive and motor tasks used were similar to real life tasks; reading silently and playing videogame while standing. The results showed that under dual task conditions; LCOP was significantly greater for the standing and videogame condition compared to the standing and silent reading and standing still conditions (figure 5).

During standing and videogame condition the individual had to constantly encode the stimulus, i.e., the Sonic game™ features, identify the appropriate response, and respond with an appropriate action by manipulating the buttons on the device to stay in the game, therefore it is apparent that the greater LCOP displacement is not just due to the cognitive processing of the task but also due to the motor component of playing the game. As for the standing still condition the individual had to maintain standing; holding the starting position, while looking at a school picture, where LCOP displacements were smaller compared to the standing and videogame condition; due to the minimal cognitive and motor components of this task. As for the standing and silent reading condition the individual had to fixate the head to provide visual fixation to read, understand, and retain the information for later questioning, therefore the individual made the least amount of LCOP displacements compared to the other two conditions.

Center of pressure velocity (COPV) is defined as the rate of change in the center of pressure displacements over the 30 seconds trial period. The COP velocity was significantly greater under standing still compared to standing and silent reading condition, also COPV was marginally significant for the standing and videogame condition compared to the stand and reading condition (figure 6). In other words, the COPV for the standing still and the standing and videogame conditions scores were similar and higher compared to the standing and silent reading condition. Again the lower COPV reported for the standing and silent reading condition is due to the nature of the task; the visual fixation and the cognitive processing and retention associated with the attentional demands of the task, made the COP rate of change minimal compared to the standing still and standing and videogame conditions. Conversely, the greater COPV reported for the standing still was mainly due to the postural corrections made to maintain the standing posture as still as possible with the arms in forward flexion and strapped wrists weights on the forearm. Similarly, the COPV for the standing and video game condition was high due the quick rate of correcting the high COP displacements; which occurred in response to the cognitive and motor components associated with that task. Thus, it could be inferred from these results that the nature of the task rather than the level of its difficulty that influenced postural performance.

The findings of this study support the work of Ramenzoni et al., (2005), Mitra & Fraizer, (2004), Pellecchia, (2003), Dault, et al., (2003), and Dault, et al., (2001). Regardless of the task type (visual, verbal, working memory) in these experiments, postural sway measures always increased under dual task conditions compared to the single task condition. Of note, the tasks used in the present study examined the effect concurrent tasks, that had cognitive and motor elements vs. what is considered purely psychological in nature, on motor performance i.e., postural performance. On the other hand, the findings of this study did not add support those of Siu & Woollacott, (2007), Swan et al., (2006), and Morioka et al., (2005). This maybe due to methodological differences related to sample size, the cognitive tasks utilized in these studies, the postural challenges used under single and dual task conditions, and the dependent variables regarding postural sway measures calculated in each study. For example, Morioka et al., 2005 examined only 17 subjects under tandem stance and narrow base of support while they carried a cup filled with water a placed on a tray and asked not to spill a drop. The nature of the task, regardless of the foot position, required the subjects to keep standing still and decrease their postural sway to avoid water spillage. In addition, the visual fixation on the glass augmented the effect of decreasing postural sway to constantly monitor the glass. Siu & Woollacott, (2007) examined only 11 subjects and their study and Swan et al., (2006) reported the time spent in balance correction (TSBC) without providing direct information about postural sway measures such as length of center of pressure , sway velocity, amplitude or frequency. Therefore it is difficult to draw comparisons between the current results and of those listed above.

The decrements in the postural performance under dual task conditions may be explained in light of the capacity sharing theory. The demands placed on the information processing system by the concurrent tasks exceeded the limits of attention resulting in decreased standing postural control.

Caution should be exercised when interpreting the results of this study. Postural sway increments do not always reflect poor standing balance especially in healthy young adult group. Rather it should emphasize on how the postural control systems of these young performers are dynamic and adapt to the task demands accordingly and how this was reflected in terms of postural sway measures under each condition.

Chapter VI

SUMMARY AND CONCLUSIONS

In this study, the influences of concurrent cognitive and motor tasks on postural sway in young adults were examined. The cognitive/ motor tasks utilized in the experiment were real life tasks that are practiced every day. The results showed that as the cognitive and motor demands of the concurrent tasks increased so did the postural sway measures, resulting in decrements in the postural control.

A limitation to this study arises from the fact that the findings can not be generalized to other age groups. The concurrent task of playing the videogame had motor elements that might have interfered with the "pure" cognitive effects of this task on postural sway and exaggerated the displacements in the center of pressure. It would have been more conclusive to add another task that had cognitive and motor elements, such as counting backwards out loud, yet produced no large body displacements, to allow for valid comparisons between the two tasks.

The outcomes of this study pose further questions that need to be answered.
What are the effects of the concurrent cognitive and motor tasks employed in this study on postural control in healthy older adults' age range 50-70 years?
What are the effects of the concurrent cognitive and motor tasks employed in this study on postural control in older adults with history of falls?

What are the effects of the concurrent cognitive and motor tasks employed in this study on postural control in adults with balance related impairments?

Does practice decrease dual task interference or does practice improve postural performance under dual task conditions? If so, does it transfer to the performance of other skills?

In conclusion, the findings from this study on healthy young adults lay the foundation for future work that allow comparison of postural sway across populations during the performance of dual tasks that require diverse cognitive elements and motor components. Future work is needed to further explore the impact of dual tasks on postural sway and its impact on the performance of everyday activities.

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APPENDIX A

SAMPLE SIZE CALCULATIONS

The sample size calculations according to Portney and Watkins* book and refereeing to appendix C page 712 & Table C.4 on page 723 under "one –way ANOVA" I used the following equations to estimate the sample size

$$Sm=\sqrt{\frac{\sum(\overline{Xi}-\overline{Xg})^2}{k}}$$ and

$$f=\frac{Sm}{s}$$

Where;

Sm is standard deviation of the means of each dependent variable across all the three trials

Xi is the mean of each DV under each condition

Xg is the grand mean of all the means

K is the number of independent groups or means

S is the standard deviation

Plugging the numbers displayed in the table below: and having $df_b = 5$ degrees of freedom; because there are five Dependent variables Length of center of pressure, sway rang and sway variability in the anteroposterior and mediolateral directions) with α=0.05 and 0.8 power the following sample size were produced for each of the dependent variables.

LCOP

$$Sm=\sqrt{\frac{(0.358654-0.03364)^2+(0.323226-0.33364)^2+(0.319041-0.33364)^2}{3}}$$

Sm= 0.01777

$$f=\frac{0.01777}{0.055001}$$

f= 0.3231 ≈ 0.3

In the table on page 732 across dfb=5 with 0.8 power n= 25

ML Range

$$Sm=\sqrt{\frac{(0.01547-0.012465)^2+(0.01067-0.012465)^2+(0.011254-0.012465)^2}{3}}$$

$$f=\frac{0.00213436}{0.01418}$$

f = 0.150519028 ≈ 0.15

In the table on page 732 across dfb=5 with 0.8 power n= 96

AP Range

$$Sm=\sqrt{\frac{(0.024521-0.021658)^2+(0.020951-0.021658)^2+(0.019503-0.021658)^2}{3}}$$

$$f = \frac{0.002108}{0.014444}$$

$$f = 0.149 \approx .15$$

In the table on page 732 across dfb=5 with 0.8 power n= 96

ML Sway Variability

$$Sm = \sqrt{\frac{(0.056509-0.052819)^2 + (0.051735-0.052819)^2 + (0.050214-0.052819)^2}{3}}$$

$$f = \frac{0.00268}{0.072618}$$

$f =$ 0.03 not in table closest value for f is 0.05

AP sway Variability

$$Sm = \sqrt{\frac{(0.1573585-0.16995)^2 + (0.18979-0.16995)^2 + (0.1617-0.16995)^2}{3}}$$

$$f = \frac{0.0141978}{0.169889}$$

$$f = 0.08 \approx .10$$

In the table on page 732 across dfb=5 with 0.8 power n= 215

What sample size?

When reviewing the literature that was used as the basis for the protocol development two articles are really the foundation. First, Morioka et. al., (2005) work was used to provide an understanding of potential subject posture /positioning and task characteristics. The arm position that I used in this current study was coping the position utilized by Morioka et al. article (please see attachment). Interestingly, in this study they measured the LCOP and the standard deviation of the mediolateral and anteroposterior directions. In addition, they compared their dependent variables under two feet positions: tandem and regular standing with eyes open and eyes closed. They found significant differences in the LCOP measures for the cognitive task compared to the other two tasks, and only found significant difference in the standard deviation of the mediolateral direction from the regular standing to the tandem standing; obviously because of the change in the base of support. The second study, Blanchard et. al., (2005) study was initially used to help provide again a frame of reference for dependent variables. In this study on children they not measured LCOP, ML and AP sway range but also measured sway variability as it would be expected that in children their posture would be less stable thus presenting with greater variability in their postural sway which we do not see in normal healthy young adults.

My preliminary findings on 16 healthy young adults between the ages of 20-40, only LCOP measure demonstrate any significant changes.

In addition, for the ML and AP sway range; it seems that the position of the arms in the forward flexion position forces the COP (center of pressure) to move more in the anteroposterior direction than in the mediolateral direction. When I calculated both for power the n would need to be close to 100. Furthermore, based upon the fact that I am not interested in changes in foot position it appears that form the literature on normal healthy young adults I would not expect to see a change in this variable.

When looking at ML & AP variability it seems based on the literature that these variables are not fully understood or give any comprehensive information about the changes in LCOP in the young healthy adults. Therefore based on the above review of the preliminary data in relationship to the literature on healthy young adults I in consultation with my committee have decided to measure LCOP as my dependent variable in this project as it will provide the most meaningful information.

When calculating the sample size from this preliminary data based on the means and standard deviations of LCOP across the different conditions n was 25 when $df_b = 5$ degrees of freedom; because there are five Dependent.

Based on the above the new n= 45 when $df_b = 1$ with $\alpha = 0.05$ and 0.8 power (table C.4, page 723).

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* Portney, L. G., & Watkins, M. P. (2000). *Foundation of Clinical Research: Applications to Practice* (second ed.). Upper Saddle River, New Jersey: Prentice-Hall, Inc.

APPENDIX B

OPERATIONL DEFINITIONS

Concurrent Dual Task: is the simultaneous performance of more than one task.

Center of Pressure (COP): is the average location of the point of force application on the support plane

Length of Center of Pressure (LCOP): is the distance of COP traveled in the 30 second trial.

Sway Range (SR): is the difference between the two extreme values for both the anteroposterior (AP) and mediolateral (ML) directions.

Sway Variability (SV): is the standard deviation of the COP in a designated direction; anteroposterior (AP) or mediolateral (ML).

Center of Pressure Velocity (COPV): is the rate of change of COP values over the 30 second trial period.

APPENDIX C

STUDY FLYER

Does doing two activities simultaneously affect your standing balance?

Volunteers wanted For Research Project	Healthy adults between the ages of 20-40 who can walk independently and have normal or corrected vision
What is being investigated?	The effect of doing two activities at the same time on standing balance
What will the volunteers do?	• Volunteers will be asked to stand quietly, stand quietly and read to themselves, or play a videogame. • Changes in normal body sway will be measured
Who are the investigators?	Dr. Genevieve Pinto Zipp, Faculty member at Seton Hall University & Muneera Alghanim, Graduate Student at Seton Hall University
Where is the study being conducted?	Functional Human Performance Lab Seton Hall University, Corrigan Hall
Want more information?	Interested in participating? Please contact Graduate Programs in Health Sciences At Seton Hall University. 973-275-2076 email: zippgene@shu.edu

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FEB 04 2009

Expiration Date
JUL 17 2009

APPENDIX D

CONSENT FORM

SETON HALL UNIVERSITY
1 8 5 6

The Influence of Concurrent Cognitive and Motor Tasks on Postural Sway in Adults

Participant Consent Form

1. Dr. Genevieve Pinto Zipp, who is a physical therapists and faculty member at Seton Hall University, and Muneera Alghanim, who is a physical therapist and a graduate student at Seton Hall University, are conducting this study.
2. The purpose of this study is to assess how standing balance may be affected when a person is doing one or more activity at a time, which demands different levels of attention. The results of this study will help identify which type of tasks requires more attention. The participant is required to come on one occasion to the Functional Human Performance Laboratory (FHPL) located in Corrigan Hall at Seton Hall University, South Orange, NJ.
3. Upon arrival to the FHPL the participant's height and weight will be measured. The participant will be asked to take their shoes and socks off and stand on a platform which has a force plate imbedded in it. The force plate is a sophisticated bathroom scale about 2 feet in length and 1.5 feet in width which is connected to a computer via a wire. When standing on the force plate pressure signals are sent to the computer to measure the amount and direction

of standing sway. The participant will be asked to stand on the force plate three times under three conditions for 30 seconds at a time. The subjects will be given rest periods through out the testing session. The three conditions participants will be asked to perform in quiet standing with arms held out at shoulder height with a 100g commercially available wrist weight attached to each wrist are:

a) Stand still for 30mseconds to measure the normal standing sway.

b) Standing while reading to oneself an age appropriate sentences hung on the wall at eye level 2 feet away from the force plate with a retention test to follow.

c) Standing while playing a videogame on a handheld gameboy.

4. Refusal or withdrawal from participation: Participating in this study is purely voluntary. If the participant chooses to take part in the study one has the right at any time to withdraw oneself from it without any penalty or loss. At any time the researcher can remove the participant from the study.

5. Anonymity/ Data Access: All information collected from the testing session will be coded, and the name of the participant will not be listed on any documents. The only paper work that will have both the name and code of the participant will be the informed consent. All study related information will be kept in locked file cabinet in the Functional Human Performance

Laboratory. The only persons with access to forms and data collected in the study will be the researchers Dr. Genevieve Pinto-Zipp and Muneera Alghanim. Names of any participants in this study will be maintained confidential and will at no time be made public. The data from the study will be stored electronically on a USB memory key and kept in a locked cabinet for 3 years and then destroyed.

6. Risks and discomforts: It is anticipated that the procedures in this study have no foreseeable risks or discomforts associated with them.
7. Benefits: The participant in this study is not likely to have any direct benefit. However, information gained from this research will help therapists who treat individuals who have problems with balance.
8. Participants in this study will not receive remuneration.
9. Request for information: Participants can at any time request more information about the study. The researcher Dr. Genevieve Pinto-Zipp, will be available via telephone 973-275-2076 to answer any questions and concerns.
10. Institutional Review Board: This project has been reviewed and approved by the Seton Hall University Institutional Review Board for Human Subjects (IRB). The IRB believes that the research procedures adequately safeguard the subject's privacy, welfare, civil liberty and rights. If there are any additional questions about the research and research subject's rights the Chairperson of Seton Hall University Review Board may be reached at 973-313-6314.

Seton Hall University
Institutional Review Board

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JUL 17 2009

11. The participant will receive a copy of this consent form. The signature of the participants identifies their willingness to participate in the study.

_______________________________________ ____________

Signature of the Participant Date

____

Printed Name of the participant

_______________________________________ ____________

Researcher's Signature Date

Assigned alphanumeric code: __________

Seton Hall University
Institutional Review Board

FEB 04 2009

Approval Date

Expiration Date

JUL 17 2009

APPENDIX E

RUNNING DATA FILES-SPSS

Dependent Variable: LCOP

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

lcop	Dependent Variable
1	LCOPSS
2	LCOPSR
3	LCOP_SG

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
Lcop	Pillai's Trace	.373	15.188 (b)	2.000	51.000	.000	.373	30.377	.999
	Wilks' Lambda	.627	15.188 (b)	2.000	51.000	.000	.373	30.377	.999
	Hotelling's Trace	.596	15.188 (b)	2.000	51.000	.000	.373	30.377	.999
	Roy's Largest Root	.596	15.188 (b)	2.000	51.000	.000	.373	30.377	.999

a Computed using alpha = .05
b Exact statistic
c Design: Intercept Within Subjects Design: lcop

Mauchly's Test of Sphericity(b)

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Lcop	.870	7.095	2	.029	.885	.914	.500

Measure: MEASURE_1
Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept Within Subjects Design: lcop

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
Lcop	Sphericity Assumed	.052	2	.026	20.318	.000	.281	40.637	1.000
	Greenhouse-Geisser	.052	1.770	.029	20.318	.000	.281	35.966	1.000
	Huynh-Feldt	.052	1.828	.028	20.318	.000	.281	37.140	1.000
	Lower-bound	.052	1.000	.052	20.318	.000	.281	20.318	.993
Error(lcop)	Sphericity Assumed	.132	104	.001					
	Greenhouse-Geisser	.132	92.046	.001					
	Huynh-Feldt	.132	95.051	.001					
	Lower-bound	.132	52.000	.003					

a Computed using alpha = .05

Estimated Marginal Means

lcop

Estimates

Measure: MEASURE_1

lcop	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	.284	.016	.252	.316
2	.288	.017	.255	.322
3	.324	.018	.288	.360

Pairwise Comparisons

Measure: MEASURE_1

(I) Icop	(J) Icop	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
1	2	-.004	.006	1.000	-.019	.010
	3	-.040(*)	.008	.000	-.060	-.021
2	1	.004	.006	1.000	-.010	.019
	3	-.036(*)	.007	.000	-.053	-.019
3	1	.040(*)	.008	.000	.021	.060
	2	.036(*)	.007	.000	.019	.053

Based on estimated marginal means
* The mean difference is significant at the .05 level.
a Adjustment for multiple comparisons: Bonferroni.

Dependent Variable: MLSR

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

Mlr	Dependent Variable
1	MLR_SS
2	MLR_SR
3	MLR_SG

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
mlr	Pillai's Trace	.090	2.515(b)	2.000	51.000	.091	.090	5.029	.482
	Wilks' Lambda	.910	2.515(b)	2.000	51.000	.091	.090	5.029	.482
	Hotelling's Trace	.099	2.515(b)	2.000	51.000	.091	.090	5.029	.482
	Roy's Largest Root	.099	2.515(b)	2.000	51.000	.091	.090	5.029	.482

a Computed using alpha = .05
b Exact statistic
c Design: Intercept Within Subjects Design: mlr

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	Df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
mlr	.741	15.306	2	.000	.794	.815	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept Within Subjects Design: mlr

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
mlr	Sphericity Assumed	.000	2	.000	1.298	.277	.024	2.596	.276
	Greenhouse-Geisser	.000	1.588	.000	1.298	.274	.024	2.062	.246
	Huynh-Feldt	.000	1.630	.000	1.298	.275	.024	2.116	.249
	Lower-bound	.000	1.000	.000	1.298	.260	.024	1.298	.201
Error(mlr)	Sphericity Assumed	.013	104	.000					
	Greenhouse-Geisser	.013	82.587	.000					
	Huynh-Feldt	.013	84.764	.000					
	Lower-bound	.013	52.000	.000					

a Computed using alpha = .05

Estimated Marginal Means

mlr

Estimates

Measure: MEASURE_1

mlr	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	.013	.002	.009	.017
2	.010	.001	.009	.012
3	.014	.002	.010	.018

Pairwise Comparisons

Measure: MEASURE_1

(I) mlr	(J) mlr	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
1	2	.003	.002	.455	-.002	.007
	3	-.001	.003	1.000	-.007	.006
2	1	-.003	.002	.455	-.007	.002
	3	-.003	.002	.274	-.008	.001
3	1	.001	.003	1.000	-.006	.007
	2	.003	.002	.274	-.001	.008

Based on estimated marginal means
a Adjustment for multiple comparisons: Bonferroni.

Dependent Variable: APSR

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

apr	Dependent Variable
1	APR_SS
2	APR_SR
3	APR_SG

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
apr	Pillai's Trace	.114	3.274(b)	2.000	51.000	.046	.114	6.547	.597
	Wilks' Lambda	.886	3.274(b)	2.000	51.000	.046	.114	6.547	.597
	Hotelling's Trace	.128	3.274(b)	2.000	51.000	.046	.114	6.547	.597
	Roy's Largest Root	.128	3.274(b)	2.000	51.000	.046	.114	6.547	.597

a Computed using alpha = .05
b Exact statistic
c Design: Intercept Within Subjects Design: apr

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
apr	.812	10.594	2	.005	.842	.867	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept Within Subjects Design: apr

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
apr	Sphericity Assumed	.001	2	.000	1.892	.156	.035	3.785	.386
	Greenhouse-Geisser	.001	1.684	.000	1.892	.163	.035	3.187	.352
	Huynh-Feldt	.001	1.734	.000	1.892	.162	.035	3.282	.357
	Lower-bound	.001	1.000	.001	1.892	.175	.035	1.892	.271
Error(apr)	Sphericity Assumed	.018	104	.000					
	Greenhouse-Geisser	.018	87.573	.000					

	Huynh-Feldt	.018	90.178	.000					
	Lower-bound	.018	52.000	.000					

a Computed using alpha = .05

Estimated Marginal Means

apr

Estimates

Measure: MEASURE_1

apr	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	.022	.003	.017	.027
2	.018	.001	.016	.020
3	.022	.002	.018	.027

Pairwise Comparisons

Measure: MEASURE_1

(I) apr	(J) apr	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
1	2	.004	.002	.290	-.002	.010
	3	-.001	.003	1.000	-.008	.007
2	1	-.004	.002	.290	-.010	.002
	3	-.004	.002	.119	-.010	.001
3	1	.001	.003	1.000	-.007	.008
	2	.004	.002	.119	-.001	.010

Based on estimated marginal means

a Adjustment for multiple comparisons: Bonferroni.

Dependent Variable: MLSV

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

mlsv	Dependent Variable
1	MLV_SS
2	MLV_SR
3	MLV_SG

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
mlsv	Pillai's Trace	.068	1.850(b)	2.000	51.000	.168	.068	3.700	.368
	Wilks' Lambda	.932	1.850(b)	2.000	51.000	.168	.068	3.700	.368
	Hotelling's Trace	.073	1.850(b)	2.000	51.000	.168	.068	3.700	.368
	Roy's Largest Root	.073	1.850(b)	2.000	51.000	.168	.068	3.700	.368

a Computed using alpha = .05
b Exact statistic
c Design: Intercept Within Subjects Design: mlsv

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
mlsv	.947	2.789	2	.248	.949	.984	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept Within Subjects Design: mlsv

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
Mlsv	Sphericity Assumed	.005	2	.003	2.214	.114	.041	4.427	.443
	Greenhouse-Geisser	.005	1.899	.003	2.214	.117	.041	4.204	.430
	Huynh-Feldt	.005	1.969	.003	2.214	.115	.041	4.359	.439
	Lower-bound	.005	1.000	.005	2.214	.143	.041	2.214	.309
Error(mlsv)	Sphericity Assumed	.121	104	.001					
	Greenhouse-Geisser	.121	98.744	.001					
	Huynh-Feldt	.121	102.382	.001					
	Lower-bound	.121	52.000	.002					

a Computed using alpha = .05

Estimated Marginal Means

mlsv

Estimates

Measure: MEASURE_1

mlsv	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	.050	.007	.036	.063
2	.051	.007	.037	.066
3	.062	.007	.048	.077

Pairwise Comparisons

Measure: MEASURE_1

(I) mlsv	(J) mlsv	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
1	2	-.001	.006	1.000	-.016	.013
	3	-.013	.007	.194	-.029	.004
2	1	.001	.006	1.000	-.013	.016

	3	-.011	.007	.368	-.029	.007
3	1	.013	.007	.194	-.004	.029
	2	.011	.007	.368	-.007	.029

Based on estimated marginal means
a Adjustment for multiple comparisons: Bonferroni.

Dependent Variable: AP

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

apsv	Dependent Variable
1	APVSS
2	APVSR
3	APV_SG

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
apsv	Pillai's Trace	.083	2.299(b)	2.000	51.000	.111	.083	4.598	.446
	Wilks' Lambda	.917	2.299(b)	2.000	51.000	.111	.083	4.598	.446
	Hotelling's Trace	.090	2.299(b)	2.000	51.000	.111	.083	4.598	.446
	Roy's Largest Root	.090	2.299(b)	2.000	51.000	.111	.083	4.598	.446

a Computed using alpha = .05
b Exact statistic
c Design: Intercept Within Subjects Design: apsv

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
apsv	.937	3.326	2	.190	.941	.975	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept Within Subjects Design: apsv

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
apsv	Sphericity Assumed	.039	2	.019	1.781	.174	.033	3.563	.365
	Greenhouse-Geisser	.039	1.881	.021	1.781	.176	.033	3.351	.354
	Huynh-Feldt	.039	1.949	.020	1.781	.175	.033	3.473	.360
	Lower-bound	.039	1.000	.039	1.781	.188	.033	1.781	.258
Error(apsv)	Sphericity Assumed	1.131	104	.011					
	Greenhouse-Geisser	1.131	97.823	.012					
	Huynh-Feldt	1.131	101.372	.011					
	Lower-bound	1.131	52.000	.022					

a Computed using alpha = .05

Estimated Marginal Means

apsv

Estimates

Measure: MEASURE_1

apsv	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	.169	.021	.126	.212
2	.139	.015	.109	.170
3	.175	.017	.141	.209

Pairwise Comparisons

Measure: MEASURE_1

(I) apsv	(J) apsv	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
1	2	.030	.021	.469	-.021	.081
	3	-.006	.022	1.000	-.061	.049
2	1	-.030	.021	.469	-.081	.021
	3	-.036	.018	.147	-.079	.008
3	1	.006	.022	1.000	-.049	.061
	2	.036	.018	.147	-.008	.079

Based on estimated marginal means
a Adjustment for multiple comparisons: Bonferroni.

Dependent Variable: COPV

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

copv	Dependent Variable
1	COPv_SS
2	COPv_SR
3	COPv_SG

Multivariate Tests(c)

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
copv	Pillai's Trace	.224	7.379(b)	2.000	51.000	.002	.224	14.758	.926
	Wilks' Lambda	.776	7.379(b)	2.000	51.000	.002	.224	14.758	.926
	Hotelling's Trace	.289	7.379(b)	2.000	51.000	.002	.224	14.758	.926
	Roy's Largest Root	.289	7.379(b)	2.000	51.000	.002	.224	14.758	.926

a Computed using alpha = .05
b Exact statistic

c Design: Intercept Within Subjects Design: copv

Mauchly's Test of Sphericity(b)

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
copv	.777	12.868	2	.002	.818	.841	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b Design: Intercept Within Subjects Design: copv

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power(a)
copv	Sphericity Assumed	5.592	2	2.796	4.223	.017	.075	8.446	.729
	Greenhouse-Geisser	5.592	1.635	3.419	4.223	.024	.075	6.906	.666
	Huynh-Feldt	5.592	1.681	3.326	4.223	.023	.075	7.100	.674
	Lower-bound	5.592	1.000	5.592	4.223	.045	.075	4.223	.523
Error(copv)	Sphericity Assumed	68.851	104	.662					
	Greenhouse-Geisser	68.851	85.036	.810					
	Huynh-Feldt	68.851	87.421	.788					
	Lower-bound	68.851	52.000	1.324					

a Computed using alpha = .05

Estimated Marginal Means

copv

Estimates

Measure: MEASURE_1

copv	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	1.681	.162	1.356	2.006
2	1.260	.131	.997	1.524
3	1.631	.181	1.268	1.994

Pairwise Comparisons

Measure: MEASURE_1

(I) copv	(J) copv	Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
					Lower Bound	Upper Bound
1	2	.420(*)	.116	.002	.134	.707
	3	.050	.181	1.000	-.399	.498
2	1	-.420(*)	.116	.002	-.707	-.134
	3	-.371	.169	.099	-.789	.048
3	1	-.050	.181	1.000	-.498	.399
	2	.371	.169	.099	-.048	.789

Based on estimated marginal means
* The mean difference is significant at the .05 level.
a Adjustment for multiple comparisons: Bonferroni.

APPENDIX F

PILOT STUDY

The Influence of Dual Task on Postural Sway

INTRODUCTION

Dual tasking is the performance of two or more tasks concurrently we dual task because it is time and energy efficient (Baker, 2007). For example, one might read or converse with another person or on the phone while standing a waiting a train. Postural control is the control of the body's position in space for the purposes of balance and orientation. Postural sway, the displacement of center of mass over the support plane, is one of the ways to measure postural control (Shumway-Cook, & Woollacott, 2006). For many years it has been considered to be a highly reflexive task. More recently postural control has bee shown to be linked to cognition and attention. Attention, or the information processing capacity of an individual, is a multifaceted construct with many component including; arousal, internal and external distractibility, cognitive speed, working memory, and the ability to shift and direct attentional resources (McCulloch, 2007). Dual task conditions were developed to study the interaction between the control of posture and cognition. The primary task usually is considered the postural task it could be standing or walking, while the secondary task is usually a cognitive or in some cases motor task that is performed simultaneously with the postural task. Measurements of the separate and simultaneous performances of the postural task and the cognitive task allow researchers to examine the interaction between both tasks. If a decline in the performance of either or both tasks occurs then it is referred to as dual task interference. Dual task interference result from the decreased attentional ability to focus on the performance of both tasks simultaneously (McCulloch, 2007).

Many theories have been developed to explain dual task interference. The bottleneck or filter theories propose that the interference is due the shared structural pathways between the postural and secondary tasks; the brain then postpone the non-priority task in favor of the operations of the priority task. On the other hand, the capacity sharing theories account that attentional capacity limits; if the performances of both task simultaneously exceed the limits of attention then the performance is of one or both tasks deteriorates (Baker, 2007).

Literature on dual task effects on postural performance is not without controversy. Some studies reported that dual task performance improves standing balance (Morioka, et al., 2005; L Swan, et al., 2004) while other stated the opposite (Dault, et al., 2003; Pellecchia, 2003). In addition, there are inconsistencies in the type of concurrent tasks utilized in the experiments, most of which were adopted from the field of cognitive psychology and do not mimic real life tasks.

Thus, the purpose of this pilot study was to examine the influences of concurrent cognitive and motor tasks on postural sway in healthy adults. It was hypothesized that postural sway in adults would be influenced by the performance of concurrent cognitive and motor tasks and that cognitive tasks would influence postural sway to a greater degree than the motor tasks.

METHODS

Participants

Twenty six volunteers (12 females, 14 males; mean age = 25.04 yrs, range = 21-37yrs) participated in this study. Participants' height ranged from 1.52 to 1.86 m (mean height =1.69 m) and weight ranged from 45.7 to 90.8 kg (mean weight =72.1). All participants were free from any condition affecting their gait or standing balance, had no range of motion restrictions at the ankle, and had normal or corrected to normal vision. Experimental procedures were approved by the Seton Hall University Institutional Review Board, and participants signed an informed consent form prior to participation in the experiment. Each participant was tested individually in a laboratory setting.

Instrumentation

Bertec Force Plate® FP 4060-08 was used to measure the dependent variables of postural sway including, length of center of pressure, sway range and variability in the mediolateral and anteroposterior directions. The applied forces were captured in three dimensions and fed to a desk top computer. Data from the force plate were acquired and processed using the Qualisys Track Manager and then analyzed in the Visual3D™, C-Motion, Inc. The reliability and validity of the Bertec Force Plate®

was established to be moderate to high with an ICC of .08 (Spradley, Goggin, & Jackson, 1996).

The Concurrent Tasks

Gentiles' taxonomy (refer to Shumway-Cook & Woollacott, 2001, page 6-7) was used to classify the difficulty levels of the secondary concurrent tasks used in the study based on the cognitive processing, sensory involvement or object manipulation, and verbal response (see table 1).

Table 2. The classification of the concurrent tasks used in the study based Gentiles' taxonomy

Concurrent Task	Steps of cognitive processing	sensory involvement or object manipulation	verbal response	Task Level of difficulty
Quite Standing	x	-	-	Easy
Standing & silent reading	xxx	-	-	↓
Standing & out loud reading	x		x	↓
Standing & counting	xx		x	↓
Standing & letter identification	xx	xx	x	↓
Standing & videogame	xxx	xx	-	Difficult

Procedures

Upon arrival to the test room subjects' height and weight were measured and were asked to remove their shoes and socks. One 15 second practice trial was administered prior to data collection for each task tested:

1. Standing still.
2. Standing while counting backwards from a designated number.
3. Standing while reading silently.
4. Standing while reading out loud.
5. Standing while identifying letters with their hands.
6. Standing while manipulating a handheld gameboy™ system.

The practice took place on the level ground in a designated testing room at the Walsh Library, Seton Hall University. After the practice trials subjects stood on the force platform for data collection. The order of presentation of the six tasks was randomly assigned to control for order effects. Each participant performed three 30 second trials of each task. The same instructions were given during the practice and experimental trials except for the practice trials the subjects were instructed to stand on the floor instead of the force platform.

For the standing task subjects were asked to stand on the force platform with their arms alongside their trunk while looking at an image of a school 0.60 m in front of them at appropriate eye level. Subjects were instructed to stand still and try not to move.

For the counting backwards task subjects were required to maintain the same position and count backwards out loud first from 50, then from 75, then from 45. For the reading quietly task subjects were required to read an eight grade level paragraph, hung on the wall in front of them at appropriate eye level 0.60 m away in a font 36, times new roman. To insure that the subjects would read the text they were told that they will be asked questions about it after the end of the testing session.

For the reading out loud task subjects were asked to read out loud an eight grade level paragraph, hung on the wall in front of them at appropriate eye level two feet away in a font 36, times new roman. They were reminded that the goal was to stay still and read the paragraph.

For the letter identification task, the I placed a plastic letter in the subjects' right and left hands and asked them to identify it with the dominant hand first. For the manipulation of a handheld gameboy™ system, the subjects were asked to stand still while playing a videogame, arms were flexed bilaterally at the elbow and close to the body.

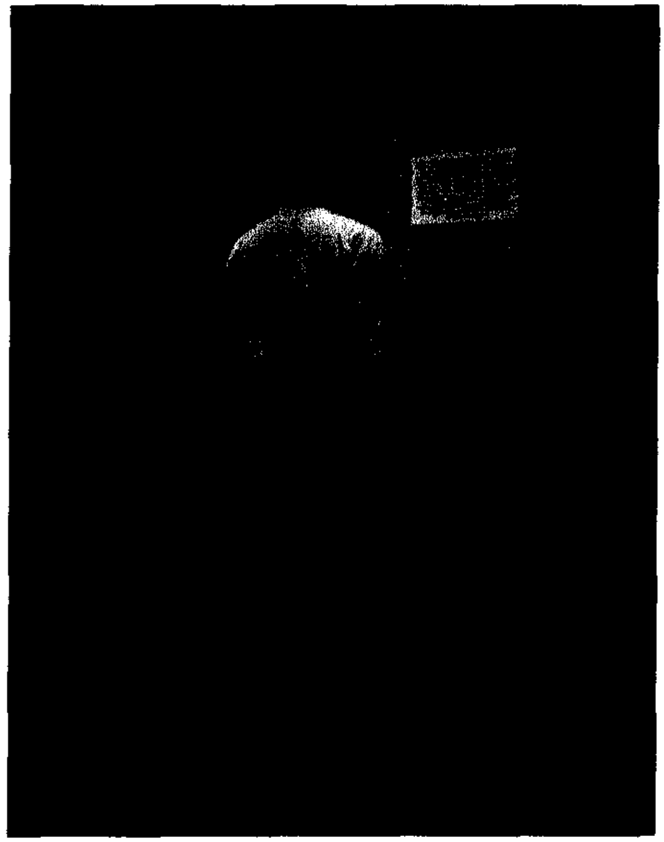


Figure 7. A subject is standing on the force plate while reading silently.

Statistical Analysis

Separate 1x6 (1 trial X 6 tasks) repeated measures analysis of variance (ANOVAs) were used to examine the effects of the six tasks and the trial on each dependent measure. The level of statistical analysis was set at $p = 0.05$. Mauchly's test of sphericity was used to ensure that the assumption of the sphericity was not violated. Pairwise comparisons with significant levels adjusted using the Bonferroni methods were used to determine differences among the means.

Results & Conclusions

The results showed that each of the repeated measures ANOVAs did not meet the assumption of sphericity using Mauchly's test; therefore the Greenhouse-Geisser corrections was used to report the results.

There were no significant effects of the concurrent tasks on LCOP $F\,(5, 125) = 0.977$, $p < 0.434$. There were no significant effects of the concurrent tasks on the sway range in the anteroposterior $F\,(5, 125) = 0.747$, $p < 0.489$, or mediolateral directions $F\,(5, 125) = 2.700$, $p < 0.053$. There were no significant effects on the sway variability in the anteroposterior $F\,(5, 125) = 0.635$, $p < 0.554$, or mediolateral directions $F\,(5, 125) = 1.00$, $p < 0.327$.

The assumption of sphericity was not met because the sample size was relatively small and this assumption is not uncommon to be violated. The results did not show any significant changes on the center of pressure measures as a function of concurrent tasks, yet the information from these tasks provided a basis for modification of the concurrent tasks types and level of difficulty, as well as the starting position for the dissertation project.

Appendix G

Power Point Presentation of the Dissertation Defense

The Influence of Concurrent Cognitive and Motor Tasks on Postural Sway in Adults

Muneera AL-Ghanim

Dissertation Committee:
Dr. Genevieve Pinto-Zipp, Chair
Dr. Marry Ann Clark
Dr. Susan Simpkins

June 15, 2009

Introduction

- Many activities of daily living require the coordinated, simultaneous performance of more than one task. e.g., standing and conversing with another person, or walking while talking on the phone.

- Referred to in the literature as
  - Dual Tasking
  - Concurrent Dual Tasking
  - Multi Tasking

(Huxhold et al., 2006; Silsupadol et al., 2006)

Postural Control

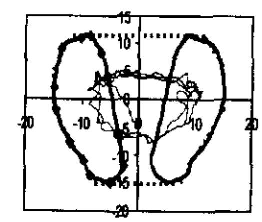
- The control of the body's position in space for the purposes of balance & orientation
- Postural Control is measured by Postural Sway

(Baker, 2007; Woollacott & Shumway-Cook, 2002)

Postural Sway

- Reflects displacement of the body's center of mass
- Postural sway varies with the stability demands of the task and environment
- Is measured as the spatio-temporal change of the center of pressure (COP), which is the average location of the point of force application on the support plane

(Baker, 2007; McCulloch, 2007; Blanchard et al., 2005)



(Christou et al.,1999)

Postural Sway …continued

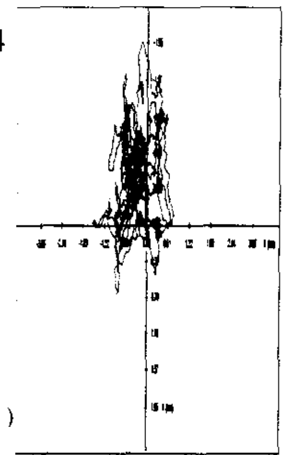
- Length of Center of Pressure (LCOP): the distance of COP traveled in the anteroposterior (AP) and mediolateral (ML) directions
- Sway Range (SR): the difference between the two extreme values for both AP & ML directions
- Sway Variability (SV): the standard deviation of the COP in the AP & ML directions
- Sway Velocity (COPV): The rate of change in the COP displacements during a time period

(Baker, 2007 ;Riley & Turvey, 2002; Shumway-Cook & Wollacott, 2007)

Normal COP Values

- LCOP in adults between the ages of 15 to 64 years is 0.14 m (140 mm)
- COP in ML direction: 0.02m (20 mm)-0.04m (40mm)
- COP in AP direction: -0.02m (-20mm)-0.01m (10mm)
- Increased COP excursions are assumed to reflect poor postural control

(Shumway-Cook & Wollacott, 2007; Elliott et al., 1998)



Blanchard, et al., (2005)

Why Dual Tasking, Postural Control, Attention?

- We are always performing tasks while standing (safety, accuracy, successful completion of tasks)
- Previously it was believed that postural control is achieved through unconscious, automatic mechanism
- However, recent experiments revealed that higher brain functions such as attention influence postural control during standing

(Morika et al., 2005; Yardley et al., 1999)

A

B

Attention

- Information processing capacity of an individual
- It is a multifaceted cognitive construct that is manifest in many ways
- Components of attention include arousal, alertness, focused attention & internal/ external distractibility, cognitive speed, sustained attention, vigilance & persistence; working memory & attention span; shifting & dividing attention, performance consistency and ability to mobilize and direct attentional resources

(McCulloch, 2007)

Dual Task Paradigms

- Developed by cognitive psychologists to examine the interaction between attention and postural control when two tasks are performed simultaneously
- Measurements of performance under single and dual task conditions allow researchers to identify the attentional demands associated with the control of posture

(O'Shea et al., 2002; Redfern, et al., 2001; Siu & Woollacott, 2007)

Dual Task Paradigms…continued

- Primary Task : task of interest or postural activity
- Concurrent Secondary Task : added task; cognitive, motor, or both which diverts attention from the performance of the primary task

Dual Task Interference

- Reduced performance of the primary, secondary, or both tasks under dual task condition is referred to as Dual Task Interference resulting from decreased attentional ability to focus on the performance of both tasks simultaneously

(McCulloch, 2007; Woollacott & Shumway-cook, 2002)

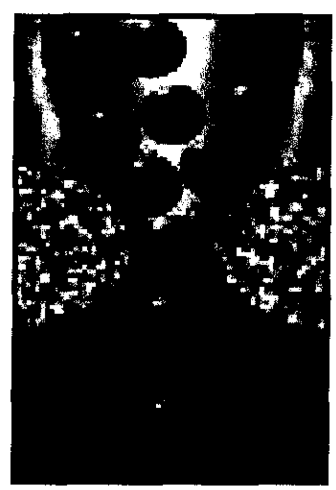
Theories of Dual Task Interference

- Bottleneck Theory
- Capacity or Resource Sharing Theory

Bottleneck Theory

- Similar tasks compete for the same structural pathways causing interference
- Operations on the non priority task are postponed in favor of operations on the prioritized task, resulting in reduced performance on the non-priority task

(Fraizer & Mitra, 2008)



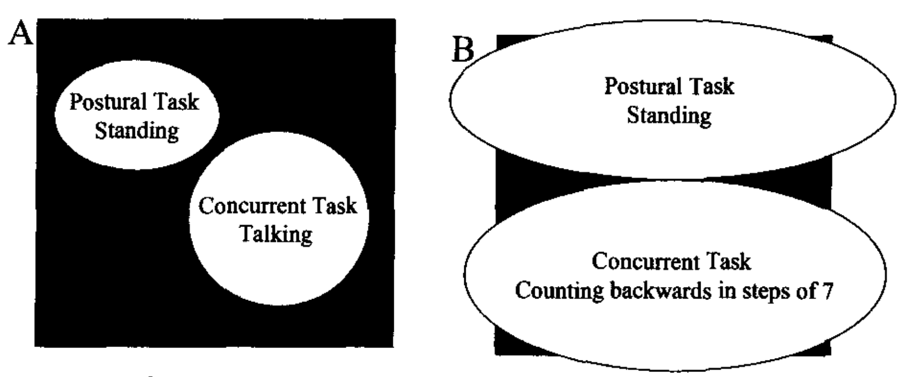
Capacity Sharing

- Attentional capacity of an individual is limited
- When performing two tasks simultaneously, attention must be divided between the tasks
- If capacity is exceeded, the performance of one or both tasks declines

(O'Shea et al, 2002; McCulloch, 2007)

Capacity Sharing Theory

- Flexible attentional capacity
- Exceeded attentional capacity



Performance +

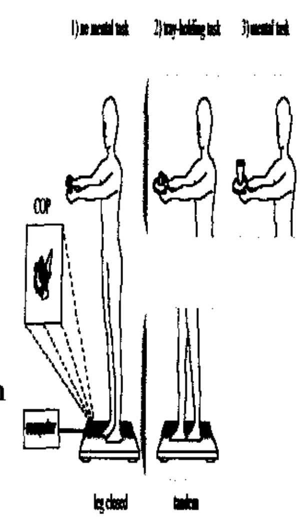
Performance ↓

Methods of Manipulating Dual Task Performance

- Inducing postural perturbations
- Manipulating the difficulty of cognitive tasks
- Focus of Attention on postural task vs. on concurrent task (different instructions)

Morioka et al., (2005)

- *n*= 17, age 19-32 years
- Holding weights in each hand, a tray with weights, & a tray with cup of water (arms were in forward flexion)
- Feet together, tandem stance, with and without vision
- Sway Path Length (SPL, or LCOP) was calculated
- SPL increased most under tandem stance due to decreased base of support
- SPL decreased under tray –water condition regardless of foot position due to the cognitive demand of preventing spilling water out of the cup



Swan et al., (2006)

- *n*= 98 women, ages 18-27 years
- Postural task: standing with feet together (easy), standing with feet together with concurrent vibratory stimulus to the bilateral gastrocnemius muscles (medium), and tandem stance (difficult)
- Cognitive task: memory task with spatial & nonsense sentences:
  "easy" level: numbers in the sentences in sequential ascending order
  "difficult" level: numbers in the sentences were randomized
- Only the difficult cognitive task had significant effects on decreasing postural sway scores, *not* the difficult postural tasks, i.e., memory recall task decreased postural sway more than did the postural challenges
- Swan et al., results support earlier findings of Andersson et al., (2002)

Siu & Woollacott (2007)

- Tested the ability to shift attention between a postural & secondary task.
- *n* = 11, age range of 20-34 years
- Focus attention to: standing alone, visual spatial memory task alone, or both tasks at the same time.
- LCOP & Verbal Response Time (VRT) were calculated
- VRT significantly improved when focus of attention was only directed towards the performance of memory task under dual task conditions
- No significant changes in the LCOP regardless of the instructions regarding the focus of attention.

Prado et al., (2007)

- 12 elderly (65-75yrs) & 12 young adults (22-39 yrs) [normal vision]
- Control task standing with eyes open (EO) blank target or eyes closed (EC)
- Visual tasks (inspection vs. search) at two target distances (near vs. far)
- Accuracy for the visual search task was calculated
- COP displacements & speed in AP and ML directions were calculated
- Older adults swayed more than younger adults in standing with eyes open
- Both groups swayed more in the ML direction during EC as compared EO. While in AP direction this effect was only observed in the elderly group

Prado et al., (2007) continued

- No significant between group differences were found for accuracy scores in the visual search task however, older adults performed slower than younger adults
- Postural sway was greater for older adults than for younger adults in all conditions. However, both young and elderly adults exhibited significant reduction in sway during the performance of the search task relative to sway during viewing a blank target (dual task condition vs. single task condition)
- Provide support to previous findings of Huxhold et al., (2006); Weeks et al., (2003)

Blanchard et al., (2005)

- Examined the influence of concurrent task on postural sway in 19 (8-10 years old) children
- Stand still (minimal cognitive processing), stand while reading out loud (moderate level of cognitive processing), stand while counting backwards (difficult level of cognitive processing)
- LCOP, sway range & sway variability in mediolateral and anteroposterior directions were calculated using AMTI Accusway System
- LCOP and sway range in ML & AP directions decreased the most in the counting backwards condition compared to reading aloud and standing still
- Postural sway decreased as the cognitive demands of the concurrent task increased in difficulty

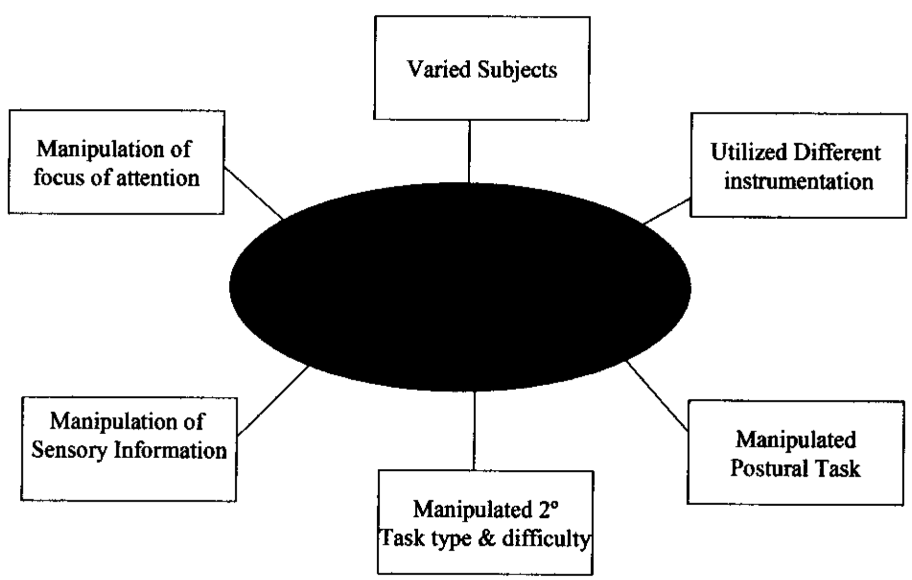
Pellecchia (2003)

- Examined the influence of cognitive tasks on postural performance
- Subjects: n= 20, (18-30 yo)
- Postural Task: standing on a compliant surface placed over the force plate
- Concurrent Tasks: different levels of difficulty
  - digit reversal (easy)
  - digit classification (moderate)
  - Counting Backwards by 3s (difficult)

Pellecchia (2003)…continued

- Dependent Variables: LCOP, AP & ML sway range and variability were calculate using AMTI force plate
- Results: *All variables were significantly greater under the standing & counting backwards condition*
- As the cognitive demands of the concurrent task increased so did the postural sway measures
- Similar findings by Dault et al., 2003; Mitra & Frazier, 2004

Summary of Different Experimental Methods in the Literature



Summary of General Findings

- Instructions to focus attention on standing posture had detrimental effects on postural performance in young healthy adults under dual task conditions
- With aging, attentional demands to perform automatic tasks; i.e., the control of posture, are increased to compensate for the deterioration in the visual, auditory, and sensory/motor systems, and loss of flexibility during quiet standing
- Inconclusive results regarding the influence of dual task performance on postural sway. Some studies found that performing a cognitive tasks while standing increases postural sway, i.e., decreases postural stability, while others found the opposite.

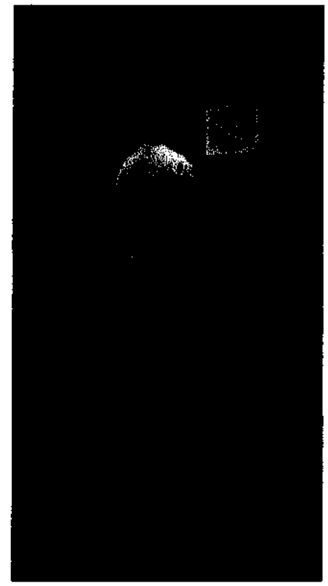
Summary of Findings.....continued

- Inconsistencies may arise from methodological confounds, reporting diverse postural sway descriptors.
  - Type of concurrent tasks
  - Type of demands of the tasks; perceptual, cognitive or retention
  - Varied Instructions
  - Used of different COP descriptors
- Interpretations of the results in that increased postural sway due to increased load is always regarded as poor postural control, rather it could be interpreted as a dynamic flexible postural control operations to meet the increasing demands of the concurrent task.

Pilot Study

- Subjects: n=26, (20-40 yrs)
- IV: 6 Tasks; SS, SRS, SRO, SL, SG ,SC
- DV: LCOP, sway range & sway variability in AP& ML directions

- No significance found *But* laid basis for modifications in the concurrent tasks and the starting position for the dissertation project



The Dissertation Question

- What are the effects of concurrent cognitive and motor tasks on postural sway in adults?

Purpose

- To examine the influences of concurrent cognitive and motor tasks on postural sway in healthy adults

Hypotheses

- Postural sway would decrease by the performance of concurrent cognitive task "reading/retention" and by the performance of concurrent cognitive/motor task "manipulating a gameboy"

- Tasks requiring more elements of "cognitive processing reading/retention" would influence postural sway to a greater degree than those requiring more "cognitive & motor elements manipulating a gameboy"

Sample size calculations

- According to Portney and Watkins, appendix C page 712 & Table C.4 on page 723 under "one –way ANOVA"
- Sm= $\sqrt{\sum \frac{(\overline{Xi} - \overline{Xg})2}{k}}$ and $f = \frac{Sm}{s}$
- For LCOP, *n= 45* when d*f*b = 1 with α =0.05 and 0.8 power

Subjects

- 47 subjects were included in the analysis; 30 females and 17 males (mean age = 25.23 yrs, range = 20-39 yrs)
  - Heights 1.50 m-1.89 m (mean height = 1.68 m)
  - Weight ranged 48-113.4 kg (mean weight = 70.16 kg)
- All participants were free from any condition affecting their gait or standing balance, had no range of motion restrictions at the ankle, and had normal or corrected to normal vision. None had a history of orthopedic, neurological disease; dizziness, balance disorders, falls, or was using medications that may affect standing balance
- All subjects completed an informed consent form that was approved by Seton Hall University IRB

Instrumentation

- Bertec Force Plate® FP 4060-08 was used to measure variables of postural sway
- The Reliability and Validity was established to be moderate to high with an ICC of .08 (Spardley et al., 1996)
- Data was collected in the Functional Human Performance Laboratory (FHPL) located in Corrigan Hall at Seton Hall University, South Orange, NJ

Independent Variables: 3 Tasks

- Position: shoulders in 90° of forward flexion, elbows extended, forearm in mid position, feet approximately 0.10 m apart.
- Standing still (SS): standing while looking at a school picture
- Standing while reading silently (SR) with follow up retention test
- Standing while manipulating a handheld gameboy™ system (SG)

Procedures

- Subjects were given a 15 second practice trial prior to data collection for each of the 3 tasks tested
- Practice trials took place on level ground in the lab
- The order of presentation of the 3 tasks was randomly assigned to control for order effects
- Subjects performed three 30 second trials of each task
- The same instructions were given during the practice and experimental trials

Dependent Variables

- Length of Center of Pressure (LCOP) : the distance of COP traveled during the 30 second trial
- Sway Range (SR): the difference between the two extreme values for both AP & ML directions
- Sway Variability (SV): the standard deviation of the COP in the AP & ML directions
- COP Velocity (COPV): rate of change of COP displacement over the 30 sec.
- Dependent measures were calculated via Visual 3D™, C-Motion, Inc.

Statistical Analysis

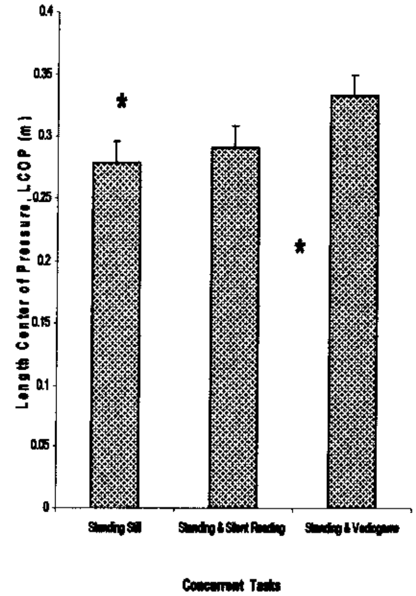
- Separate 1x3 (1trials x 3tasks) one way repeated measures analysis of variance (ANOVAs) was used to examine the effects of the 3 tasks and the mean of the 3 trials on each of the dependent measures. The level of statistical significance was set at $p=0.05$
- Mauchly's test of sphericity was used to ensure that the assumption of sphericity was not violated
- Pairwise comparisons using the Bonferroni method for determining the differences among the means were reported

Results

Effects of concurrent tasks on LCOP

- The overall test for differences in means in the repeated-measures ANOVA was significant, $F(2, 104) = 20.32, p = 0.029$
- LCOP under SG condition was significantly ($M = 0.324$, $SE = 0.018$) greater than under the SR ($M = 0.288$, $SE = 0.017$) & SS ($M = 0.284$ $SE = 0.016$) conditions

Results…continued



- Length of center of pressure (LCOP) in meters as a function of concurrent tasks, * indicates significant level at p= 0.05.

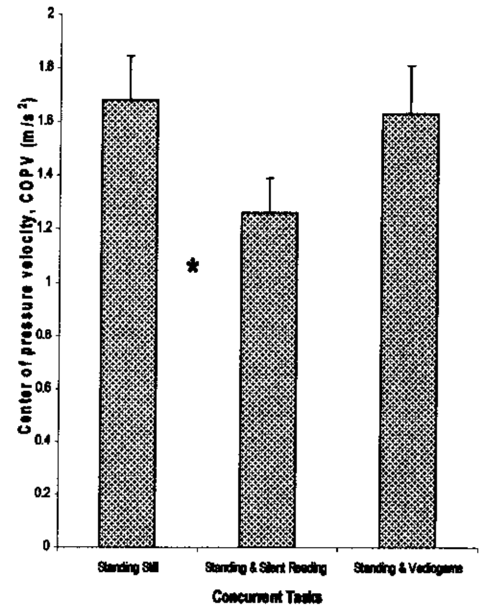
Results…continued

Effects of concurrent tasks on COPV

- The overall test for differences in means in the repeated-measures ANOVA was significant, $F\,(2, 104) = 1.78, p = 0.017$.
- COPV under SS ($M = 1.681$, $SE = 0.162$) was significantly greater than under the SR ($M = 1.260$, $SE = 0.131$) condition.
- COPV under the SS and SG conditions was similar

Results…continued

- Center of pressure velocity (COPV) in meters/ second2 as a function of concurrent tasks. * indicates significant level at p= 0.05.



Results...continued

- There were no significant effects of concurrent tasks on other dependent variables ; ML & AP sway range and variability.

AP Sway Range	$F\,(2, 104) = 1.29$	$p < 0.277$
ML Sway Range	$F\,(2, 104) = 1.89$	$p < 0.16$
AP Sway Variability	$F\,(2, 104) = 2.21$	$p < 0.11$
ML Sway Variability	$F\,(2, 104) = 1.78$	$p < 0.17$

Discussion

- The nature of each task in regard to the cognitive elements and motor components explains the effects of the conditions on the LCOP and COPV

- The results give further support to those of Ramenzoni et al., (2005), Mitra & Fraizer, (2004), Pellecchia, (2003), Dault, et al., (2003), and Dault, et al., (2001)

Discussion...continued

- The results are inconsistent with those reported by Siu & Woollacott, (2007), Swan et al., (2006), and Morioka et al., (2005).

- The findings of this study may be explained by the capacity sharing theory: The demands placed on the information processing system by the concurrent tasks exceeded the limits of attention resulting in decreased standing postural control.

Summary

- The influences of concurrent cognitive and motor tasks on postural sway in young adults were examined. The cognitive/ motor tasks utilized in the experiment were similar to real life tasks that are performed every day.
- The results showed that as the cognitive and motor demands of the concurrent tasks increased so did the postural sway measures, resulting in decrements in the postural control.

Limitations

- The findings can not be generalized to other age groups.
- The concurrent task of playing the videogame had motor elements that might have interfered with the "pure" cognitive effects of this task on postural sway and exaggerated the displacements in the center of pressure.
- It might have been more conclusive to add another task that had cognitive and motor elements, such as counting backwards out loud, yet produced no large body displacements, to allow for valid comparisons in terms of postural sway measures between these two tasks; standing and videogame and standing and counting.

Conclusions

- Caution should be exercised when interpreting the results of this study. Increases in postural sway do not always reflect poor standing balance especially in healthy young adults.

- Future research is needed to address the impact of the performance of everyday activities on postural sway in older age groups with/ without a history of falls, and in individuals with balance impairments.

Questions

- E-mail: muneera.alghanim@student.shu.edu
  muneera.alghanim@gmail.com

THANK YOU

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