EFFECTS OF SINGLE- VS. DUAL-TASK TRAINING ON BALANCE

PERFORMANCE UNDER DUAL-TASK CONDITIONS IN

OLDER ADULTS WITH BALANCE IMPAIRMENT:

A RANDOMIZED, CONTROLLED TRIAL

by

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PERFORMANCE UNDER DUAL-TASK CONDITIONS IN OLDER ADULTS

WITH BALANCE IMPAIRMENT: A RANDOMIZED, CONTROLLED TRIAL

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Among older adults, an impaired ability to maintain balance while simultaneously performing cognitive tasks is a common occurrence. Because poor dual-task balance performance is associated with increased fall risk and a decline in cognitive function, interventions to improve dual-task balance performance are needed. Although traditional rehabilitation programs emphasizing training balance under single-task conditions are effective in improving single-task balance performance, it is not known whether single-task training generalizes to balance control under dual-task contexts. Moreover, the effectiveness of approaches to training balance under dual-task conditions is not known.

Thus, the purposes of this study were to determine whether elderly individuals with balance impairment can improve their balance performance under dual-task conditions; to investigate whether training balance under single-task conditions

generalizes to balance control during dual-task contexts; and to evaluate the effect of instructional set on dual-task balance performance. Specifically, the efficiency of three different training strategies was examined in an effort to understand the mechanisms underlying training-related changes in dual-task balance performance. Twenty-three elderly adults with balance impairment were randomly assigned to 1 of 3 interventions: single-task balance training (ST); dual-task training with fixed-priority instruction (FP); and dual-task training with variable-priority instruction (VP). Clinical and laboratory measures were obtained at baseline and after training. In addition, selected clinical outcomes were repeated after the second week of training to examine interim balance change and at twelve weeks post training to test retention.

Results indicate that dual-task training was effective in improving balance under dual-task conditions in the elderly with balance impairment. Training balance under single-task conditions may not generalize to balance control during dual-task contexts. Explicit instruction regarding attentional focus was an important factor for improvement in dual-task performance. The VP instructional set offered advantages over the FP instructional set in terms of the degree of improvement, the rate of learning, and the retention of the dual-task training effect. The dual-task processing skills learned during training were not transferred to novel dual-task conditions. Lastly, the training benefits acquired during VP training could be the result of both automatization of the individual task and the development of task-coordination skills.

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CHAPTER I

INTRODUCTION

Falls are the leading cause of accidental death among older adults.[1-3]

Approximately 30% of people over 65 years of age fall at least once a year.[4,5] Falls are

costly and have potentially devastating physical, psychological, and social consequences.

Nonfatal falls often lead to physical injury, reduced levels of activity, loss of confidence,

and changes in lifestyle.[5-7] Although most falls involve multiple factors, it was shown

that balance impairment is a major contributor to falling in elderly people.[1,5,6,8-10]

Recent research has demonstrated that an impaired ability to maintain balance

while simultaneously performing cognitive tasks is associated with increased rates of

adverse outcomes, such as falls[11-14] and cognitive and physical functional decline[15-17] in

elderly people. Because interventions designed to improve dual-task balance performance

have the potential to reduce falling rate and functional decline, they are a critical health

care need.[18-20]

A number of studies have shown that traditional rehabilitation programs,

emphasizing training balance under single-task conditions, are effective in improving

single-task balance performance in older adults.[21,22] However, it is not known whether the

traditional single-task balance training is effective in improving balance performance

under dual-task contexts. Moreover, the effectiveness of different approaches to training balance under dual-task conditions is not known.

Thus, the primary goal of this series of studies is to investigate the effects of individualized training on dual-task balance performance in older adults with balance impairment. Specifically, the relative efficacy of three different training strategies is examined in an effort to understand the mechanisms underlying training-related changes in dual-task balance performance. A literature review on pertinent topics is provided in the following sections.

Balance Control in Older Adults

Balance control has been defined as the ability to maintain the body's center of mass within the base of support. Maintaining balance involves sensory detection of postural changes through sensory inputs (i.e. visual, vestibular, and somatosensory), integration of sensorimotor information within the central nervous system (i.e. the cerebellum, brainstem, basal ganglia, and sensorimotor cortex), and execution of appropriate musculoskeletal responses (i.e. limb and trunk muscles which receive impulses via the spinal cord and peripheral nerves). The deterioration of these systems with aging can lead to balance impairment and falls.

A wealth of research has documented age-related changes in many systems that contribute to an increased likelihood of falls in the elderly. Some examples of musculoskeletal changes include reduction in muscle strength and endurance, and joint

flexibility.[23-25] Examples of age-related changes in sensory systems include deterioration of proprioception or joint-position sense,[26,27] reduced visual acuity and contrast sensitivity,[28,29] and a progressive loss of vestibular hair cells and nerves.[2,30] Finally, example of changes in the central nervous system include loss of neurons and dendrites, decreases in the number of giant pyramidal cells within the motor cortex, a progressive loss of neurons and depletion of neurotransmitters (e.g. dopamine) within the basal ganglia, and changes in the dendritic tree of motor neurons in the spinal cord.[31-33]

These age-related changes affect maintenance of balance control in steady state balance (i.e. the ability to provide background postural tone and remain balance during quiet stance), reactive balance (i.e. the ability to recover from an unexpected perturbations to balance), and anticipatory balance (i.e. the ability to anticipate and minimize instability associated with performance of tasks). It has been suggested that age-related impairment of the different sensory systems and an impaired ability to generate hip-abductor and hip-adductor torque are responsible for the observed lateral sway during quiet stance.[34] Deterioration of the proprioceptive system and ankle muscle weakness can delay the reactive postural responses.[35] In addition, age-related changes in the visual system lead to a reduced ability to use visual information to alter gait patterns in anticipation of upcoming obstacles in the walking path.[36]

Balance Control under Dual-Task Conditions

The control of balance, whether in static or dynamic conditions, is an essential requirement for daily activity. It has long been known that postural control is subserved by neural pathways at spinal and supraspinal levels that constitute reflexes and synergies. These reflexes and synergies form the basis for a fast response to body perturbations. For example, reactive adjustments can be initiated in as little as 70 milliseconds and act to return the body center of mass to a position over the base of support.[37,38] Thus, postural control has traditionally been considered an automatic task requiring minimal higher cognitive processing.

In contrast to this traditional view, more recent investigations provide evidence that the regulation of posture and locomotion involves higher cognitive resources. Dual task methodology, which requires subjects to perform a postural task and a cognitive task simultaneously, has been used to assess the cognitive demands necessary for performing postural tasks. The underlying assumptions for a dual-task paradigm are derived from a well-known "capacity sharing" model of information processing.[39-41]

According to this model, information-processing capacity is limited and these limited resources could be shared among all tasks in a graded fashion (also known as graded capacity sharing). Dual-task interference will be observed only if two tasks require common limited resources. Because there is less capacity for each individual task during which the capacity is shared, the performance on at least one task will be impaired. It is assumed that one could voluntarily allocate the capacity among different tasks and the efficiency of the task performance is proportional to the amount of capacity

allocated to it (e.g. the performance increases when more capacity is allocated to that task).[39]

Studies using dual-task methodology in postural control seem to support the capacity-sharing model. Dual-task experiments show alterations in the performance of the postural task,[42-44] the cognitive task,[45-47] or both tasks.[48-52] In other words, the demands of controlling postural tasks can lead to a reduction in the capacity to perform a concurrent attentionally demanding cognitive task. Reciprocal effects of cognitive tasks on the postural tasks have also been observed. For example, a significant change in gait parameters (e.g. a significant increase of double-support time) was seen when a memory task and a fine motor task were executed concurrently during walking.[48]

Although postural tasks are attentionally demanding in all age groups, they appear to be more attentionally demanding in older adults, particularly in older adults with balance impairment.[53] For example, elderly individuals with balance impairment who had been able to maintain stability in a single-task condition were unable to maintain stability when a secondary cognitive task was added.[44,54]

Dual-Task Balance Performance as a Predictor of Falls and Cognitive Decline

Recently, it has been reported that impaired dual-task balance performance can be used to predict falls in elderly people.[11-14] For example, Faulkner and colleagues (2007) examined the relationship between changes in dual-task gait performance and a history of recurrent falls.[12] They found that walking more slowly while performing a visual-spatial decision task is associated with higher odds of recurrent fall history.[12] In addition, a study by Lundin-Olsson and colleagues (1997) demonstrated that people who stopped walking when talking had an increased tendency to fall.[13] Thus, they suggested that the tendency to stop walking when talking can be used as a predictor of falls in older adults. Melzer and colleagues (2007) also found that the voluntary step execution test under dual-task conditions can identify older adults who are at risk for falls. Participants who spent longer time ($\geq$ 1,100 ms) on a stepping task under dual-task conditions had 5 times greater falling risk than those who spent less time on the task.[14]

Dual-task balance performance has also been associated with cognitive and physical functional declines.[15-17] Research by Coopin et al. (2006) showed that walking speed under dual-task conditions was associated with executive function.[15] Participants with poor executive function walked significantly slower when picking up an object, compared to those with good executive function.[15] Moreover, Pettersson et al.(2007) and Manckoundia et al. (2006) found that balance performance under dual-task conditions can be used to identify people with Alzheimer's disease.[16,17]

Dual-Task Training using Non-Balance-Related Tasks

A large body of literature in postural control has shown the positive effect of rehabilitation programs using a task-oriented approach on balance performance under single-task contexts.[21,22,55,56] The task-oriented approach emphasizes improving movement strategies within a given environment in order to achieve a desired functional task.[22] From theses studies, only two have implemented dual-task training combining a traditional task-oriented program with a variety of cognitive tasks; one was a case study with a limited sample size,[57] and the other dealt with healthy young adults.[58] Thus information on effective approaches to training balance under dual-task conditions in the elderly population is limited; however there is information on dual-task training that is not balance-related. Kramer and colleagues (1995) used a monitoring task in conjunction with an alphabet-arithmetic task to examine the effects of training on attentional control in dual-task settings.[59] Participants in their study were trained with either a fixed-priority (FP) or a variable-priority (VP) instruction. The participants in the FP group were instructed to equally emphasize both tasks, whereas those in the VP group were required to vary their priorities between the two tasks. They found that the VP group improved (i.e. increased accuracy and decreased response time) significantly more than the FP group and more importantly, the dual-task processing skills learned during VP training transferred to novel tasks.[59]

Models: Practice Effects on Dual-Task Performance

Although the mechanisms underlying changes in dual-task performance in postural control are not known, there is information on dual-task processing using cognitive tasks. At least two models have been proposed to account for the training-related changes in dual-task performance. First, the task automatization model proposes that the improvement in dual-task performance is the result of automatization of the individual tasks. Because the automatized tasks require fewer or no limited central capacity resources, they should produce less or no interference with other tasks, respectively.[60] Thus, this model predicts that improvement in dual-task performance would occur after practicing the tasks either separately (single-task training) or together (dual-task training), since automatization of the tasks could happen even after practicing the tasks in the dual-task settings.[60,61]

Secondly, the task integration model suggests that an efficient integration of the two tasks acquired during dual-task training is crucial for the improvement of dual-task performance.[60,61] During dual-task training, participants could learn to organize the tasks so efficiently that the shared capacity resources are minimized. Therefore, this model predicts that improvement in dual-task performance would be observed only following dual-task training, not single-task training.[60]

Purpose of the Study

Despite the potential importance of interventions to improve dual-task balance performance in elderly people, no studies have examined whether the traditional single-task rehabilitation program is effective for the improvement of balance performance under dual-task conditions. In addition, the most effective approaches to training balance under dual-task conditions are not known. Thus, the purpose of this study was to examine the effectiveness of single-task and dual-task training programs on balance performance under dual-task conditions in older adults with balance impairment.

Bridge

The goal of the first study were to determine whether older adults with balance impairment can improve their balance performance under dual-task conditions; to investigate whether training balance under single-task conditions generalizes to balance control during dual-task contexts; to examine the effect of instructional set on dual-task balance performance, and to evaluate the feasibility of individualized training programs in dual-task settings.

CHAPTER II

THE EFFECTS OF SINGLE- AND DUAL-TASK TRAINING ON BALANCE

PERFORMANCE UNDER DUAL-TASK CONDITIONS

Introduction

Among older adults, the inability to maintain balance under dual-task conditions is a common occurrence. Because impaired dual-task balance performance predicts adverse outcomes such as falls,[11-13] and declines in both cognitive and physical function,[15-17] interventions that improve dual-task balance performance are a critical health care need.[18,19]

Several studies have shown the positive effect of task-oriented training on balance and gait functions in a wide variety of populations including older adults,[21,22] and individuals with stroke.[55,56] Two studies have shown that dual-task balance performance can be improved with training; however one was a case study with limited sample size,[57] the other dealt with a stroke population.[62] Thus information on effective approaches to training dual-task balance performance is limited; however there is information on dual-task training that is not balance related. Work by Kramer et al.[59] using cognitive tasks demonstrated that dual-task training allowed participants to practice coordinating the 2 concurrent tasks. In addition, the instructional set regarding attentional focus (fixed

priority [FP] versus variable priority [VP]) was an important factor when training under dual-task conditions. The participants who received dual-task training with VP instructions (shifting attention between tasks) learned tasks faster and performed better than those who received training with FP instructions (placing equal amounts of attention on both tasks). Whether this framework will be effective in training dual-task balance performance in elders is not known.

The purpose of this double-blinded, randomized controlled pilot study was to compare the effect of three different approaches to balance training on dual-task walking performance in community dwelling older adults with impaired balance. The intervention used task-oriented training under single- and dual-task conditions. We hypothesized that dual-task training (including FP and VP groups) would be more effective at improving balance performance under dual-task conditions than single-task balance training. In addition, this study examined the effect of instructional set on dual-task performance. Based on Kramer's work, we hypothesized that dual-task training with VP instructions would be superior to dual-task training with FP instructions in terms of the rate of learning achieved during dual-task training. This study was designed as a pilot study to examine the feasibility of our training methods, and to verify that older adults could in fact adhere to the instructional sets.

Methods

Participants

Fifty older adults with balance impairment were recruited through flyers in the Eugene and Springfield, OR communities. Two steps of eligibility screening were performed. An initial telephone interview screen based on the following inclusion criteria: (1) age 65 years or older, (2) be able to walk 10 m with or without an assistive device (but without the assistance of another person), (3) no neurological or musculoskeletal diagnosis that could account for possible imbalance such as cerebral vascular accident, Parkinson's Disease, cardiac problems, transient ischemic attacks, significant orthopedic involvement, significant visual and auditory impairments, and (4) approval of their primary care physician to participate (Appendix A). The second screening was performed using clinical tests to determine balance impairment. Persons were considered balance impaired if they scored less than 52 (out of a total of 56 points) on the Berg Balance Scale (BBS),[63,64] and/or completed a 10-Meter Walk with a self-selected gait speed of ≤ 1.1 m/s.[65,66] Scoring less than 52 on BBS[64] and a self-selected gait speed of ≤ 1.1 m/s[67,68] are associated with a decline in the ability to maintain balance during stance and gait, respectively. Persons were ineligible for the study if they scored less than 24 on the Mini Mental State Examination (MMSE) (Appendix B). A score of 24 and lower suggested decreased cognitive function (e.g. dementia).[69] All testing was conducted in the Motor Control Laboratory at the University of Oregon, Oregon.

Randomization

After completing the written informed consent in accordance with the Human Subjects Compliance Committee of the University of Oregon (Appendix C), participants who met the eligibility criteria were randomly assigned to 1 of 3 training groups: 1) single-task balance training (ST); 2) dual-task training with fixed priority instructions (FP); and 3) dual-task training with variable priority instructions (VP). Since it was not possible to train all participants simultaneously, we divided participants into two blocks (blocks of 12 participants) and then randomly assigned an equal number of participants to each of the treatments using opaque, sealed envelopes which were selected by a blindfolded person. The appropriate envelope was opened and the card inside told if the participant was to be in the ST, or FP, or VP groups. Participant's name and the group he/she belonged to were then written down. This study was a double-blind, randomized controlled trial in which neither the testers nor the participants knew the groups the participants belonged to.

Interventions

All participants received 45-minute individualized (one trainer to one participant) training sessions, 3 times a week for 4 weeks. The duration and intensity of this training were chosen based on previous studies which showed that 10- to 12-hour balance training[70,71] and 1-to 5-hour dual-task training [59,72,73] programs were effective in improving balance function and dual-task performance in older adults, respectively. For

each training session, there were 4 separate training stations and each station was led by at least one trainer. Thus, there were 4 participants trained in each training session. Each participant underwent a 12-minute training session at each station and then rotated to the next station, until he/she completed all 4 stations (including 3 minutes of rest). As a result, all participants received the same amount of contact time with each trainer. The first intervention session began in October 2006 and the last session was completed in June 2007.

Across 12 sessions, balance activities, using a task-oriented approach, progressed participants from body stability, to body stability plus hand manipulation, then body transport, and finally body transport plus hand manipulation.[74] The activities given in station 1 and 2 were body stability tasks (with and without hand manipulation), and in station 3 and 4 were body transport (with and without hand manipulation). Examples of body stability included standing with eyes closed, tandem standing, and standing on compliant surfaces. Examples of body stability plus hand manipulation included standing on foam with rapid alternating hand movement, tandem standing while holding a basket, and throwing and catching a ball while standing. Body transport activities included walking with a reduced base of support, walking backward, and transferring from one chair to another chair. Lastly, body transport activities plus hand manipulation included repeating body transport tasks while carrying a basket or while tossing a ball. One additional trainer was assigned to record balance and cognitive performance during the training sessions.

The participants in the control single-task balance training group (ST) received balance activities under single-task conditions (only balance tasks were given). The participants in the dual-task training with FP instructions practiced the same set of balance tasks as the single-task training group, while simultaneously performing cognitive tasks. The participants in this group were instructed to maintain attention on both postural and cognitive tasks at all times. Finally, the participants in the dual-task training with VP instructions participated in the same set of activities as the FP group, but under a different instructional set. During each session, half of the training was done with a focus on postural task performance, and half was done with a focus on cognitive task performance. During these sessions, data on both balance and cognitive performance was recorded to confirm that the participants actually allocated attention to one task or the other. For example, during the narrow base walking within the lines while counting backward by threes, the numbers of missteps were increased when attention was shifted to the counting backward task, but decreased with a shift in attention to the narrow walking task. Similarly, number of responses on the counting backward task depended on whether attention was directed toward the narrow walking task or the counting backward by threes task. This design has been employed previously in the case study by Silsupadol et al. 2006.[57]

Trainers in this study included 3 physical therapists and 2 research assistants in the Department of Human Physiology. All the trainers underwent a 5-hour training, which included studying all the techniques and the procedures used in the study, and learning how to give the appropriate instructions for each training group. None of the

trainers performed the testing or knew the participants' testing scores in order to ensure proper blinding. All trainers were evaluated 12 times during the study to assure compliance with training protocols and to make sure that the tasks were modified so that the level of the difficulty were appropriate for each participant.

Outcomes

Enrolled participants completed a health survey questionnaire providing information on age, living environment, medical history, current co-existing medical conditions, self-reported history of falls, and type of assistive device used for ambulation (Appendix D). Then, participants underwent a baseline evaluation using a combination of standardized clinical measures that evaluate balance function under single- and dual-task conditions.

The primary outcome measure for this study was self-selected gait speed performed under single and dual task conditions (Appendix E).[65,66] The participants were asked to walk for 10 meters at their comfortable speed. Only the middle 6 meters, however, were timed to eliminate the effects of acceleration and deceleration. In the dual-task condition, participants were asked to give a response to continuous simple addition/subtraction questions (e.g. 2+4) while they were walking. The single-task and dual-task conditions were randomized with 2 trials collected for each condition. Average values were used for analysis.

Gait speed was chosen as a primary outcome performance variable because it has been reported as a global indicator of functional performance in older adults.[75,76] It was shown to be a good predictor of physical performance (e.g. the ability to cross a street,[67] the ability to perform activities of daily living[77]), mortality,[75] and falls.[66,78,79] In addition, gait speed is easily obtained and clinically interpretable. A minimal detectable change (MDC: minimal amount of change that is not due to measurement errors) and a minimal clinically important difference (MCID: the smallest change that is considered to be important to an individual) for gait speed under single-task conditions in older adults have been reported to be 0.05 m/s[80] and 0.1 m/s,[75,80] respectively. However, no values have been reported in the literature for gait speed under dual-task conditions.

Secondary outcomes included the Berg Balance Scale (BBS),[63] and the Activities-specific Balance Confidence Scale (ABC).[81] The BBS, a 14-item test, was used to quantify balance performance under single-task conditions on tasks such as standing unsupported with eyes open and closed, standing unsupported with feet together, and picking up an object from the floor (Appendix F). Scores range from 0 to 56, with higher scores suggesting better balance. The MDC for the BBS has been reported to be 3 points for older adults with balance problems who require no assistive device and 5 points for older adults who require an assistance device for ambulation.[82,83]

The ABC was used to determine self-reported confidence when performing 16 different daily activities without an assistive device, such as walking around the house, walking up and down stairs, reaching, walking across a parking lot, and walking on slippery floors (Appendix G). A confidence rating scale ranges from 0% - 100%, with 0%

indicating no confidence, and 100% indicating full confidence. No MDC values have been reported for ABC.

All measures were collected at baseline and at the end of training. In addition, the primary outcome measure was repeated after the second week of training in order to examine interim balance change and at twelve weeks following the end of training to test retention. All testing was conducted by a trained research assistant in the Department of Human Physiology. He underwent 10 hours of training, including studying the procedures and techniques used for the testing. He also performed the testing with 10 participants who were not in this study to assure compliance with testing protocols. He was evaluated by the trained physical therapist during all testing sessions.

Sample Size

The sample size and power calculations were performed with G*Power3 (a statistical power analysis program).[84] The effect size computation was based on our pilot study on the primary outcome measure. With a sample size of 6 in each group, a mixed-effects repeated-measure ANOVA will have 80% power to detect the interaction effect size of 0.34 at the .05 level of significance, assuming a correlation between repeated measures of 0.6 and the sphericity assumption of 1. Due to the possibility that a small number of subjects would drop out over the course of the study (a 20% attrition rate), a total of 24 subjects was targeted for this study.

Statistical Analysis

Baseline characteristics were compared among intervention groups using a one-way analysis of variance (ANOVA) for quantitative variables and the chi-square test for qualitative variables. The training effects on all measure outcomes, except gait speed, were determined using a 2-way mixed-effects repeated measures ANOVA with intervention group (ST, FP, VP) as the between-subjects factor and time (pretraining, posttraining) as the within-subjects factor. The training effect on gait speed data was performed using a 3-way mixed-effects repeated measures ANOVA with group (ST, FP, VP) as the between-subjects factor and time (pretraining, posttraining) and testing condition (single-task testing, dual-task testing) as within-subject factors. To test the effects of training approaches, the intervention changes in primary and secondary outcomes were compared between the single-task balance training group and the dual-task training groups (including FP and VP groups), using planned analyses. To test the effects of instructions, the intervention changes in primary and secondary outcomes were compared between dual-task training with FP instructions and dual-task training with VP instructions, using planned analyses. Partial Eta-Squared values were reported as measures of effect size. Independent and dependent t tests also were conducted to examine changes across groups and changes across time, respectively. Data analysis was performed using SPSS version 15.0 for Windows (SPSS Inc, Chicago, IL).

Results

A total of 50 older adults were evaluated for potential enrollment (Figure 2.1). Of these individuals, 17 people did not meet the inclusion criteria (14 individuals had neurological or musculoskeletal diagnosis that could account for possible imbalance and 3 older adults did not meet the criteria of having balance impairment). Of 33 people who may have been eligible, 8 declined to participate in the study after the telephone screening and 2 after the in-person evaluation. Twenty-three older adults who met the eligibility criteria and agreed to participate were randomly assigned to 1 of 3 training groups. All 23 individuals received intervention as they were originally allocated. Of 23 participants, 22 completed the training program. One participant in the ST group passed away due to a car accident after the 3rd week of training. Even though all participants who completed the training sessions were evaluated at the end of the training, we excluded the data from one participant in the VP group who had a surgical examination right before the post-training testing. Twenty-one participants returned for 12-week follow-up testing. The process of recruitment began in April 2006 and the follow-up testing was completed in September 2007.

The primary analysis was performed using an intention-to-treat basis. For all baseline measures, we report on all participants (n=23). For the effect of intervention, data from 21 participants were available for the intention-to-treat analysis. There were no adverse events associated with participation in the study.
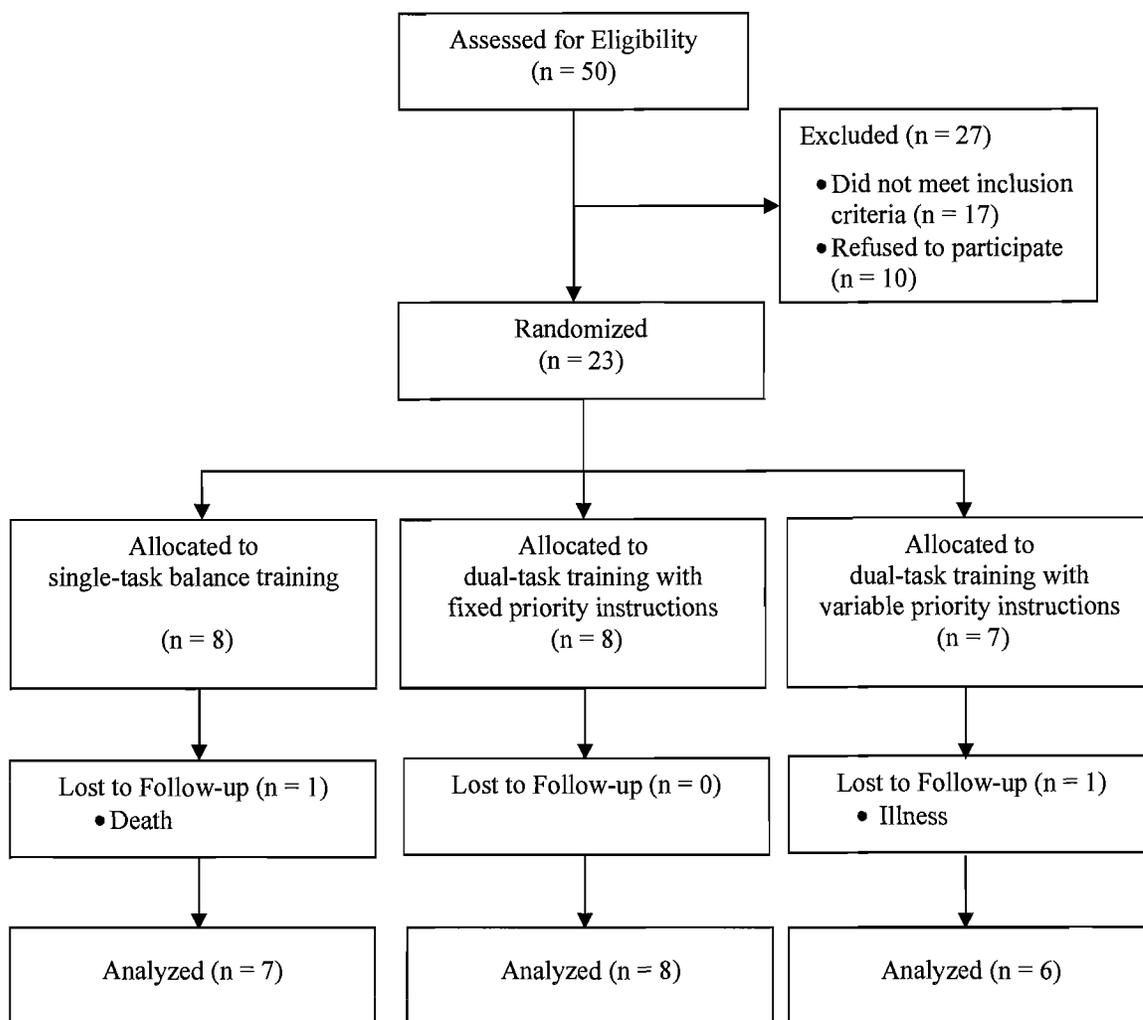
Figure 2.1. Flow diagram of participant progress through phases of randomized trial.

Baseline Characteristics

The mean age of the participants at enrollment was 74.8 years (standard deviation

5.9, range 65-85 years). Most participants were female (18 out of 23). Table 2.1

summarizes the baseline demographic and clinical characteristics. The baseline

characteristics were equivalent across the intervention groups (P>.05) for all variables.

Table 2.1. Baseline demographic and clinical characteristics by intervention group. Values are mean ± standard deviation for quantitative variables and number for qualitative variables.

Characteristic	Single-Task Balance Training (ST) (n = 8)	Dual-Task Training Fixed Priority (FP) (n = 8)	Dual-Task Training Variable Priority (VP) (n = 7)	P
Age	74.38 ± 7.29	74.38 ± 6.16	75.86 ± 4.26	.87
Female, n	8	6	4	.51
Number of falls (the previous year)	1.25± 1.49	1.13± 1.64	1.14 ± 0.90	.98
Number of losing balance without a fall	2.78± 3.51	2.03 ± 3.10	2.24 ± 3.27	.90
Berg Balance Scale (0-56)	50.50 ± 4.47	47.25 ± 6.61	47.14 ± 6.64	.46
Single task self-selected gait speed (m/s)	1.17 ± 0.11	1.12 ± 0.26	1.07 ± 0.25	.64
Dual task self-selected gait speed (m/s)	1.11 ± 0.11	0.98 ± 0.21	0.97 ± 0.22	.29
The ABC Scale (0-100%)	73.81 ± 14.86	76.60 ± 24.84	69.19 ± 15.14	.75
The Mini Mental State Examination (0-30)	29 ± 1.60	27.5 ± 1.77	28.86 ± 0.90	.12

Effect of Intervention

The results from the mixed-effects repeated-measures ANOVA showed that the group x time x testing condition interaction was not significant for gait speed (P=.54, effect size=0.07). However, we found a significant group x time interaction for gait speed under dual-task conditions (P=.03, effect size=0.34) (Table 2.2). A priori analyses revealed that the dual-task training groups demonstrated significantly greater improvements in gait speed under dual-task conditions compared to the single-task training group (P=.008) (Fig. 2.2). Participants who received dual-task training with FP and VP instructional sets walked significantly faster after the training when they had to simultaneously perform a cognitive task (P<.001, effect size=0.57 and P<.001, effect size=0.46, respectively). However, no significant difference in walking speed under dual-task conditions between pre- and post-score was found for the single-task training group (P=.46, effect size=0.03). Figure 2.3, a scatter plot with line of equivalence, demonstrates the training effect for each participant in all intervention groups. Any individual above the line of equivalence was a participant who improved after the training. The number of responses and the number of errors participants made on the mathematics tasks were comparable across groups both at baseline and at the end of training (P=.72, effect size=0.04 and P=.85, effect size=0.02, respectively).

Table 2.2. Findings on outcome measures at pre-training (Pre), the end of training (Post), and change scores by intervention group.

Measure	Single-task Balance Training Group (ST) (N = 7)			Dual-task Training with Fixed-priority Instruction Group (FP) (N = 8)			Dual-task Training with Variable-priority Instruction Group (VP) (N = 6)			P^*	$P^{\dagger,\ddagger}$
	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change		
BBS (0-56)	50.00 ± 4.58	55.29 ± 1.25	5.29	47.25 ± 6.61	54.50 ± 2.45	7.25	49.00 ± 4.90	54.00 ± 2.76	5.00	.50	.65† .30‡
Single-task gait speed (m/s)	1.20 ± 0.10	1.23 ± 0.14	0.03	1.12 ± 0.26	1.28 ± 0.21	0.16	1.12 ± 0.22	1.21 ± 0.22	0.09	.35	.24† .45‡
Dual-task gait speed (m/s)	1.12 ± 0.11	1.15 ± 0.12	0.03	0.98 ± 0.21	1.16 ± 0.20	0.18	1.03 ± 0.16	1.20 ± 0.23	0.17	.03	.008† .83‡
ABC (0 – 100%)	72.67 ± 15.67	85.87 ± 11.67	13.20	76.60 ± 24.84	78.91 ± 20.50	2.31	69.78 ± 16.49	73.72 ± 15.83	3.94	.01	.004† .66‡
Number of responses	2.86 ± 0.80	3.14 ± 0.63	0.28	2.81 ± 0.75	3.06 ± 0.32	0.25	3.17 ± 1.21	3.67 ± 1.03	0.5	.72	.75† .45‡
Error rate	0.10 ± 0.14	0.06 ± 0.07	0.04	0.13 ± 0.12	0.04 ± 0.07	0.09	0.10 ± 0.11	0.03 ± 0.07	0.07	.85	.62† .81‡

Values presented as mean $\pm$ SD for pre- and post-training scores. [*] Group x Time interaction effect. [†] As calculated by comparing single-task training group vs. dual-task training groups (FP and VP), using *a priori* analyses. [‡] As calculated by comparing FP group vs. VP group, using *a priori* analyses
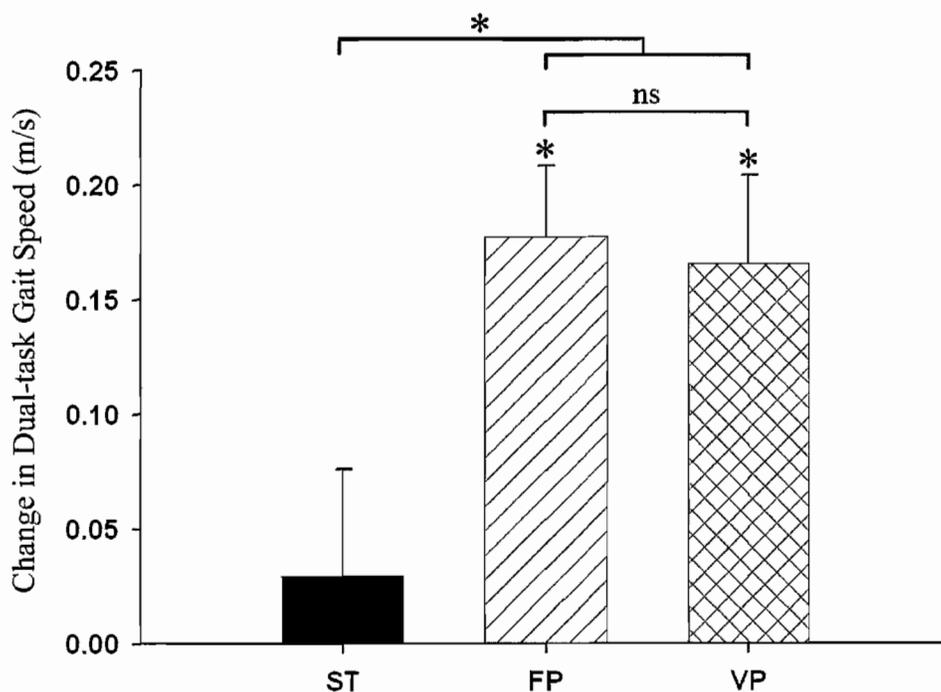
Figure 2.2. Bar graph of change (post testing - baseline) on self-selected walking speed under a dual-task condition (walking + mathematics task) by group (mean ± standard error). Solid bar represents single-task balance training group (ST); lined bar represents dual-task training with fixed-priority instructions (FP); hatched bar represents dual-task training with variable-priority instructions (VP). Significant baseline to post intervention changes indicated by asterisk above bar. Planned comparisons demonstrating group differences indicated by horizontal lines above bars.

For gait speed under single-task conditions, the group x time interaction was not significant (P=.35, effect size=0.11), resulting from the equivalent amount of improvement in walking speed across all training groups. However, we found a significant main effect of time (P=.02, effect size=0.27), indicating that participants in all training groups walked significantly faster under single-task conditions (i.e. when no cognitive task was added) after the training.
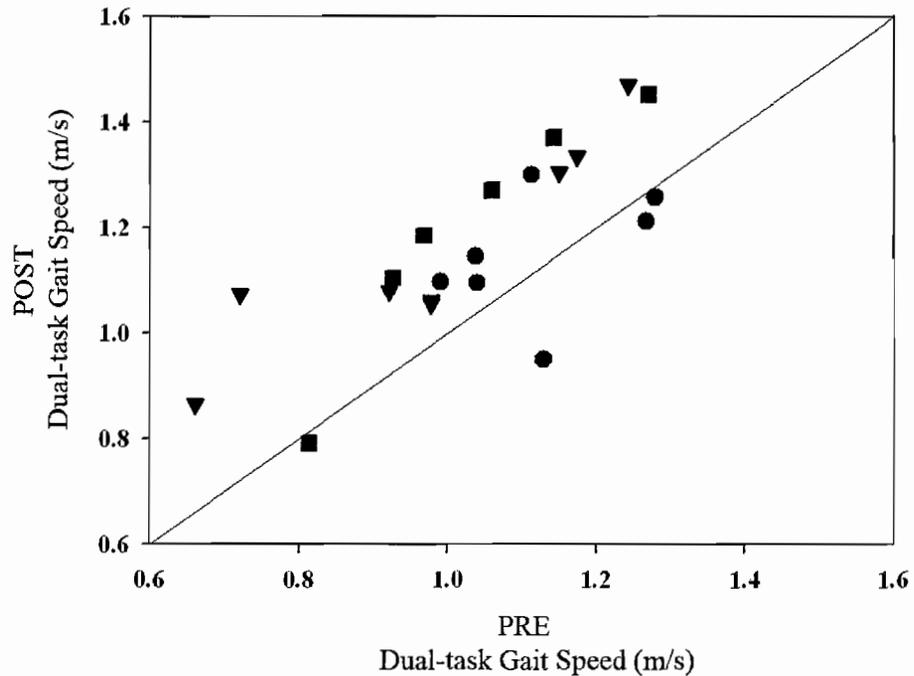
Figure 2.3. Scatter plot with line of equivalence of self-selected walking speed under a dual-task condition (walking + mathematics task) before and after the training. Circle represents the single-task balance training group (ST); triangle represents the dual-task training with fixed-priority instructions (FP); rectangle represents the dual-task training with variable-priority instructions (VP). Any individual above the line of equivalence is a participant who improved after the training.

There was a significant main effect of time ($P<.001$, effect size=0.72) on the BBS, suggesting that all participants significantly improved their balance performance under single-task conditions at the end of the training. However, no significant group x time interaction ($P=.50$, effect size=0.07) and no significant main effect of group ($P=.66$, effect size=0.05) were found, indicating that the improvements on the BBS were comparable across the training groups.

In addition, the results from the mixed-effects repeated-measures ANOVA revealed a significant group x time interaction for the ABC scale (P=.01, effect size=0.38). A priori analyses revealed that participants who received single-task balance training increased their level of confidence when asked to perform daily activities more than participants who received dual-task training (P=.004). In fact, only the single-task balance training group showed a significant increase in their confidence after training (P<.001, effect size=0.61).

To test the effect of instructional sets during dual-task training, a priori analyses compared dual task balance training under FP versus VP instructional sets. The results showed that the performance on all primary and secondary outcome measures were comparable across the two dual-task training groups (P>.05). However, only the dual-task training group with VP instructions demonstrated a dual-task training effect on gait speed under dual-task conditions at the end of the 2nd week of training and this training effect was maintained after 12 weeks of training (P=.003, and P=.006, respectively).

To verify that participants could in fact adhere to the instructional sets during VP training, the number of missteps on the narrow walking task and the number of responses on the counting backward by 3s task were evaluated during each training session. A successful trial was defined as the ability to reduce the numbers of missteps when attention was shifted to the narrow walking task and increase the numbers of responses when the attention was directed toward the counting backward by threes task. Percent of success was then calculated by the number of successful trials divided by the total number of trials and multiplied by 100. The results showed that all participants in the VP

group could allocate their attention to the task to which they were asked (the average

percent of success = 80%, range 70%-88%).

<div align="center">Discussion</div>

This randomized controlled trial provides evidence that our individualized

training programs were effective in improving balance control under single-task contexts

in older adults with balance impairment. After the 4-week intervention program,

participants in all training groups significantly improved performance on the Berg

Balance Scale (BBS), and single-task gait speed. In fact, 18 and 15, respectively, (out of

21) older adults exceeded the boundaries of the minimal detectable change for the BBS (3

points), and the self-selected gait speed under single-task conditions (0.1 m/s). Overall,

the BBS scores increased about 5.85 points (from 48.75 to 54.60), suggesting a 40%

reduction in fall risk.[64] In addition, the overall gait speed increased from 1.14 m/s to 1.24

m/s, suggesting that their performances were closer to the performance of healthy older

adults without balance problems at the end of training.[65] According to Bohanon, the mean

gait speeds of healthy older adults are 1.33 m/s, and 1.27 m/s for men and women,

respectively.[65] In addition, the participants' gait speed after the training was higher than

1.22 m/s, the speed required to cross the street safely.[67]

Even though both single-task and dual-task training programs were equally

effective at improving balance performance under single-task conditions, dual-task

training programs were superior to single-task training in improving walking under dual-

task contexts. We found that participants who received dual-task training (either with

fixed or variable instructional sets) demonstrated greater improvements in self-selected gait speed under dual-task conditions. In fact, only participants who received dual-task training walked significantly faster after the training, when simultaneously performing a cognitive task. This finding suggests that older adults are able to improve their balance performance under dual-task conditions only following specific types of training and that training balance under single-task conditions may not generalize to balance control during dual-task contexts. According to the Task Integration Hypothesis, practicing two tasks together (not a single-task practice) allows participants to develop task-coordination skills. Thus, one possible explanation of this outcome is that the efficient integration and coordination between the 2 tasks acquired during dual-task training is crucial for improving dual-task performance.[59]

Alternatively, according to the Task Automatization Hypothesis, practicing only one task at a time (single-task training) allows participants to automatize the performance of individual tasks. As a result, the processing demand required to perform the tasks is decreased, leading to a more rapid development of skills.[59,60] However, the results from this study and other labs[20,85] did not support the Task Automatization Hypothesis. For example, the research by Voelcker-Rehage and Alberts demonstrated that the ability to coordinate multiple tasks did not improve after extended single-task practice.[20] It is possible that participants in our study received a variety of balance activities and we did not specifically evaluate the tasks that they trained regularly.

One of the important issues in training studies is whether the benefit of training is retained several months after the training has ended. We found that the training effect on single-task performance was maintained at the 12-week follow-up in all training groups. However, the training effect on dual-task performance was maintained at 12-week follow-up only in the participants who received dual-task training with variable priority instructions (VP). This result may indicate the importance of instructions when training balance control under dual-task contexts. Research by Kramer and colleagues[59] suggests that participants who receive dual-task training with VP instructions have the advantage over those who receive training with FP instructions. These researchers found that participants in dual-task training groups with either FP or VP instructions could learn to coordinate the two tasks. However, after training, the processing demand required to perform the tasks was less when their attention was shifted between the two tasks, as was required in the VP group.[59] This could explain why the participants in our VP group were able to learn the tasks faster (i.e. training effect at the 2nd week of training) and were able to maintain their skill level for a longer period of time (i.e. training effect at 3-month follow-up) than our FP group.

Although the gait speed at baseline was found to have no significant difference between groups, the fact that participants in the single-task training group walked at 1.11 m/s, compared to about 0.97 m/s for FP and VP groups, at the beginning of training may have limited the training effect. In addition, because the group x time x testing condition interaction was not significant, this suggested that the type of training was not only crucial for improvement in dual-task balance performance but also important for

improvement in balance performance under single-task contexts. Dual-task training programs, which were found to be effective in improving dual-task balance performance, might also be superior to single-task training in improving single-task balance performance. Thus, it is not clear whether the training effect found in this study is specific to balance performance under dual-task conditions. With enough statistical power, we might observe the similar training effect on single-task balance performance as well. Another limitation of the study was the use of only gait speed to quantify performance under dual-task conditions. Even though gait speed was shown to be a good indicator of physical performance,[67,77] mortality[75] and falls,[78,79] there are several other measures that could be used. For example, the center of mass and center of pressure inclination angles have been shown to be a sensitive measure of balance control during gait in the elderly.[68]

This study also showed that only the participants in the single-task balance training group increased their self-reported confidence when performing daily activities. One possible explanation for this finding is that the activities (balance + cognitive tasks) we gave to the participants in the dual-task training groups were much more difficult than the tasks (only balance tasks) given to the participants in the single-task training group. As a result, the balance skills of the participants in the dual-task training groups were continually challenged and this may have resulted in a reduced confidence in performing daily tasks. It is also possible that changes in cognitive constructs such as confidence and self-efficacy do not change at the same rate as physical function. Further research is necessary to understand this finding.

This study found that it was feasible to implement individualized dual-task training, combining a traditional task-oriented intervention with a variety of cognitive tasks, in community-dwelling older adults with balance impairment. We also found that older adults could in fact adhere to the instructional sets regarding attentional focus. They successfully allocated their attention to the task to which they were instructed (the average percent of success was 80%). Thus, results may generalize to similar older adults with balance impairment, excepting those with significant neurological or musculoskeletal diagnosis.

In summary, dual-task training is effective in improving balance control under dual-task contexts in elderly individuals with impaired balance and single-task training may not generalize to balance performance under dual-task conditions. Instructional set was an important contributing factor for improvement in dual-task performance. The variable priority instructional set offered advantages over the fixed priority instructional set in terms of the rate of learning and the ability to maintain the skill level achieved during training. Additional research is needed to understand the underlying mechanisms of improving balance performance under dual-task conditions.

Bridge

Chapter II determined whether older adults with balance impairment can improve their balance performance under dual-task conditions; it investigated whether a traditional rehabilitation program emphasizing training balance under single-task conditions was

effective in improving balance control during dual-task contexts; and it evaluated the effect of the instructional set on dual-task balance performance.

Chapter III investigated the mechanisms underlying training-related changes in dual-task balance performance of older adults with impaired balance. Specifically, the effect of three different training strategies on dual-task balance performance and the generalizability of dual-task processing skills to novel tasks were examined using the same population as those in Chapter II.

CHAPTER III

TRAINING-RELATED CHANGES IN DUAL-TASK BALANCE PERFORMANCE

Introduction

An impaired ability to maintain balance while simultaneously performing cognitive tasks has been associated with adverse outcomes, such as falls,[11-14] and physical and cognitive functional decline[15-17] in elderly people. Despite the potential importance of intervention to improve dual-task balance performance,[18,19] there have been very few studies[57,58,62] evaluating the efficacy of strategies to train balance under dual-task conditions. Previous studies have included either a small sample size,[57] or have focused on other populations such as healthy young adults[58] or patients with stroke.[62] None of those studies was directly designed to uncover the mechanisms underlying dual-task balance processing.

It has been suggested that understanding the mechanisms of dual-task processing will lead to the development of an optimal strategy to improve dual-task performance.[60,72] Although the mechanisms underlying changes in dual-task performance in postural control are not known, there is information on dual-task processing using non-balance-related tasks. At least two models have been proposed to account for the training-related

changes in dual-task performance. The task automatization model proposes that improved dual task performance is the result of increased automatization of the individual tasks. This model predicts comparable improvement in dual-task performance with either single-task training or dual-task training.[60,61] Alternatively, the task integration model suggests that an efficient integration of the two tasks acquired during dual-task training is crucial for the improvement of dual-task performance.[60,61] Consequently, improvement in dual-task performance would be observed only following dual-task training, not single-task training.

The ability to modulate attention may also play an important role in the acquisition of dual-task coordination skill.[59] A study by Kramer et al compared dual-task training under two instructional sets; the variable-priority (VP) group were required to vary their priorities between the two tasks, whereas the fixed-priority (FP) group were instructed to equally emphasize both tasks.[59] Results favored the use of VP instructional set, since the VP group improved (i.e. increased accuracy and decreased response time) significantly more than the FP group and more importantly, the dual-task processing skills learned during VP training transferred to novel tasks. It is not known, however, whether similar training effects would be observed when training balance under dual-task conditions using Kramer et al.'s framework.

Thus, the purpose of this randomized controlled study was to compare the efficiency of three different training strategies in an effort to understand the mechanisms underlying training-related changes in dual-task balance performance of older adults with balance impairment. Specifically, the effect of training strategies on dual-task balance

performance and the generalizability of dual-task processing skills to novel tasks were examined. In accordance with the task automatization hypothesis, we predicted equivalent training benefits in dual-task balance performance from both single-task training (ST) and dual-task training (FP and VP) groups. Alternatively, based on the task integration hypothesis, it was expected that there would be improvement in dual-task balance performance only following dual-task training, not single-task training. In addition, based on Kramer's work, it was predicted that dual-task training using VP strategy would be superior to training using FP and ST strategies, and the dual-task processing skills acquired during VP training would generalize to other dual-task balance conditions, not directly trained.

Methods

Participants

Elderly persons were recruited through flyers in the Eugene and Springfield, OR communities. Individuals were initially screened over the telephone based on the following inclusion criteria: age 65 and older, able to walk 10 m with or without an assistive device but without the assistance of another person, and no neurological or musculoskeletal diagnosis that could account for possible imbalance such as cerebral vascular accident, Parkinson's Disease, cardiac problems, transient ischemic attacks, significant orthopedic involvement, significant visual and auditory impairments. An in-person physical examination followed the initial telephone screen. Balance impairment

was determined using the Berg Balance Scale (BBS),[63,64] and self-selected gait speed,[65,66] previously shown to correlate with balance during stance[64] and gait.[67,68] Persons were eligible for the study if they scored less than 52 out of a total of 56 points on BBS,[63,64] and/or walked with a self-selected gait speed of ≤ 1.1 m/s. [65,66] Inclusion criteria also required participants to score more than 24 on the Mini Mental State Examination.[69] Written informed consent, in accordance with the Human Subjects Compliance Committee of the University of Oregon, was obtained from all participants.

Randomization

Participants were randomly assigned to one of three training groups: 1) single-task balance training (ST); 2) dual-task training with fixed priority instructions (FP); and 3) dual-task training with variable priority instructions (VP). Since the study involved one on one training, it was not possible to train all participants at the same time. Thus, the participants were divided into two blocks (blocks of 12). We then randomly assigned the same number of participants to each of the interventions using opaque envelopes which were selected by a blindfolded person at the end of all baseline testing. This study was a double-blind, randomized controlled trial in which both the participants and the persons who administered the tests were blinded from group assignments and from the randomization procedure.

Interventions

Participants who were randomized to the control ST group received 12 balance-training sessions under single-task conditions, using a task-oriented approach. This approach emphasized improving movement strategies within a given environment in order to achieve a desired functional task.[22] The activities given in this study followed the taxonomy of movement tasks which progressed participants from body stability, to body stability plus hand manipulation, then body mobility, and finally body mobility plus hand manipulation.[22] Body stability activities involved tasks such as standing on one leg, tandem standing, and standing on compliant surfaces. Body stability plus hand manipulation involved tasks such as standing on foam with rapid alternating hand movement, tandem standing while holding a basket, and throwing and catching a ball while standing. Body mobility activities included tasks such as transferring from one chair to another chair, walking with a reduced base of support (narrow walking), and walking backward. Finally, body mobility plus hand manipulation included repeating body mobility tasks while tossing a ball or carrying a basket.

The participants in the dual-task training with FP instructions practiced the same set of balance tasks as the ST group, while performing additional cognitive tasks simultaneously. Examples of cognitive tasks included counting backward, naming things such as animals and flowers, and spelling words backward. Individuals in this group were instructed to always pay attention to both balance and cognitive tasks. Lastly, the participants in the dual-task training with VP instructions participated in the same set of activities as the FP group, but under a different instructional set. During each training

session, they were asked to vary their priorities between the postural tasks and the cognitive tasks as follows: 1) pay more attention to postural tasks; 2) pay more attention to cognitive tasks; and 3) equally emphasize both tasks. To verify that the participants could truly shift their attention between tasks, data on both balance and cognitive performance were recorded.[57] For example, during the narrow walking task while counting backward by threes, the number of missteps increased when attention was shifted to the counting backward task, but decreased with a shift in attention to the narrow walking task. Similarly, the rate of response on the counting backward task decreased or increased when attention was directed toward the narrow walking task vs. the counting backward by threes task, respectively.

To examine the effect of single task automatization, a paradigm using a practiced task (i.e. the tasks that were trained in every training session) was used. A narrow base walk was used as the practiced task, with no additional task for the single-task training group, and while counting backward by threes for the dual-task training groups. Obstacle crossing in conjunction with the Auditory Stroop task was used to test whether the dual-task processing skills generalized to a novel task (i.e. a task that had never been trained).

All participants received 45-minute training sessions, three times a week for four weeks. Previous research has shown that 12-hour balance training[70,71] and 5-hour dual-task training [59,72,73] programs improved balance and dual-task performance in elderly persons. Four training stations allowed four participants to be trained at the same time. Participants spent 12-minutes at each station before moving to the next, until they completed all four stations. A rest period of three minutes was provided. Overall, the

participants had the same amount of contact time with each trainer. All trainers, including three physical therapists and two research assistants in the Department of Human Physiology, received five hours of practice with the techniques and protocols used in the study. The trainers were also evaluated at least twice a month to assure compliance with training protocols and to verify that the exercise program was customized to each participant's ability (i.e. continually challenging but safe). None of the trainers administered the tests or knew the participants' testing scores.

Assessment Protocol

Before and after 12 training sessions, each participant was instructed to walk at their preferred pace six meters under two single-task (narrow walking, and obstacle crossing) and two dual-task (narrow walking while counting backward by 3s, and obstacle crossing with an auditory Stroop task) conditions. For the narrow walking task, two strips of tape were secured to the floor; the distance between the two strips was normalized to each participant as 50% of their anterior superior iliac spine width. The number of missteps (stepping onto or outside either strip of tape) was recorded. For the obstacle crossing task, individuals were asked to walk and step over an obstacle set at 10% of the person's body height using an adjustable bar which was placed at the 3-meter mark.

For the narrow walking while counting backward by 3s task, the participants were asked to walk between the two strips of tape while simultaneously counting backward by threes from varying starting numbers. The total number of responses and accuracy were

recorded. For the obstacle crossing with auditory Stroop task, the words "high" (spoken at a high or a low pitch), and "low" (spoken at a high or a low pitch) were presented while walking over an obstacle. To confirm that individual always performing two tasks simultaneously, the Stroop task was presented continuously. The participants were instructed to report the pitch (high or low) of the voice as quickly and as accurately as possible while ignoring the meaning of the word itself. Following a response, the next word was presented within 1000 milliseconds. The verbal reaction time (VRT: the time between the presentation of a stimulus and the onset of the subsequent verbal response) and the congruency effect (VRT difference between the congruent and incongruent conditions) were examined. In the congruent condition the meaning and pitch of the word were similar (i.e. the word "high" was presented at a high pitch or the word "low" was presented at a low pitch). Participants performed both concurrent cognitive tasks in sitting as well as while walking.

Experimental Apparatus

An eight-camera motion analysis system (Motion Analysis Corp., Santa Rosa, CA) with a set of 29 reflective markers were used to capture whole-body motion. Three-dimensional marker trajectory data were collected at a sampling rate of 60 Hz, and filtered using a fourth-order Butterworth low-pass filter with a cutoff frequency of 8 Hz. Reflective markers were placed bilaterally on bony landmarks of each participant. For the lower extremities, markers were placed over the dorsum of the feet (between 2nd and 3rd metatarsal heads), posterior aspect of the heels (at the same level with foot marker),

lateral malleoli, lateral aspect of the shanks, lateral femoral epicondyles, lateral aspect of the thighs, and anterior superior iliac spines. In addition, one marker was placed on the sacrum. For the trunk and upper extremities, markers were placed over the tip of the acromion processes, lateral humeral epicondyles, the dorsal aspects of the wrists (midway between radial and ulnar styloid), and the 3rd metacarpal heads. For the head-neck segment, markers were placed on the top, the front, temporal and the back of the head. Additionally, markers on the medial femoral epicondyles and medial malleoli were used in a static condition to estimate knee and ankle joint centers. One offset marker was placed on the right scapula to distinguish left from right on the participants. Two markers were also placed on the tip of each end of the obstacle. The biomechanical human model consisted of thirteen body segments, six for the lower extremities, four for the upper extremities, one for the pelvis, one for the trunk, and one for the head. This model was used to compute segmental center of mass locations.[86]

The participants wore a safety harness attached to a trolley system secured to a concrete ceiling to guard against falling. All testing, conducted by a physical therapist and trained research assistants in the Department of Human Physiology, was performed at baseline and at the end of training in the Motor Control Laboratory, University of Oregon. All testers underwent 10 hours of training, including studying the procedures, techniques, and equipment used for the testing.

Outcomes

The primary outcome measure for this study was the average frontal plane center of mass (COM) and ankle joint center (AJC) inclination angle. This angle is formed by the intersection of the line connecting the COM and AJC with a vertical line through the AJC (Figure 3.1). The inclination angles were computed throughout the single stance phase of gait. The COM and AJC inclination angle was chosen as a primary outcome measure because research by Lee and Chou[68] demonstrated that the inclination angle between the COM and center of pressure (COP) was a sensitive measure of balance control during gait, with a smaller angle indicating better balance performance. In their study, the COP was calculated using the ground reaction forces and moments derived from 2 force plates. In order to accurately calculate the COP, a single foot placement is required on each force plate. However, the elderly with balance impairment in the present study walked with a short step length and we could not adjust our force plates so that each foot landed on one force plate. As a result, calculation of the COP was not possible for this study, thus calculation of the AJC was performed instead. It was shown by Chen and Chou[87] that using ankle markers, rather than the COP, for the formation of the inclination angle is an alternative measure to distinguish persons with impaired balance from healthy elderly.

COM

Ankle joint center

Figure 3.1. An illustration of the center of mass (COM)-ankle joint center inclination angle in the frontal plane

The secondary outcomes included the number of missteps for the narrow walking task, the rate of response and the response accuracy for the counting backward by threes task, and the verbal reaction time (VRT) and the congruency effect for the auditory Stroop task. Only trials with correct responses were included for VRT analysis.

Sample Size

The sample size was determined based on our pilot study, using G*Power3 (a statistical power analysis program).[84] A priori, repeated-measure ANOVA indicated that a total sample size of 18 was needed to achieve 80% power to detect the interaction effect size of 0.34 at the .05 level of significance. With a potential 20% attrition rate, a total of 24 participants were targeted for this study.

Statistical Analysis

An intention-to-treat analysis was performed using SPSS version 15.0 for Windows (SPSS Inc, Chicago, IL). Baseline characteristics were compared among groups using a one-way analysis of variance (ANOVA) for quantitative variables and the chi-square test for qualitative variables. The intervention effects on all outcome measures, except VRT, were determined using a 3-way mixed-effects repeated measures ANOVA with group (ST, FP, VP) as a between-subjects factor and time (pretraining, posttraining) and testing condition (single-task testing, dual-task testing) as within-subjects factors. The intervention effect on VRT data was performed using a 4-way mixed-effects repeated measures ANOVA with group (ST, FP, VP) as a between-subjects factor and time (pretraining, posttraining), congruency effect (congruent, incongruent), and testing condition (single-task testing, dual-task testing) as within-subject factors. Partial Eta Squared values were reported as measures of effect size. To examine changes across groups and across time, a one-way ANOVA and dependent t tests were performed, respectively, using a Bonferroni adjustment.

Results

Fifty older adults were initially recruited for the study, 17 did not meet the inclusion criteria and 10 declined to participate. Of the 17 individuals not meeting inclusion criteria, 14 individuals had significant health problems that could account for possible imbalance and 3 older adults did not meet the criteria of having balance impairment. Twenty-three eligible older adults were randomly assigned to 1 of 3 training groups; 21 completed the training program (one person in the ST group passed away and one person in the VP group had an unrelated surgical procedure). Data from the 21 participants at the 12-week follow-up testing were used in the intention-to-treat analysis. No adverse events occurred during the study.

Baseline Characteristics

Baseline demographic and laboratory characteristics of intervention groups are presented in Table 3.1. On average, the participants were 75 years of age at enrollment (standard deviation 6.1, range 65-85 years). Most participants were female. There were no significant group differences in any baseline characteristics (P>.05)

Table 3.1. Baseline demographic and laboratory characteristics by intervention group.

Characteristic	Single-Task Balance Training (ST) (n = 7)	Dual-Task Training: Fixed Priority (FP) (n = 8)	Dual-Task Training: Variable Priority (VP) (n = 6)	*P*
Age	74.71 ± 7.80	74.38 ± 6.16	76.00 ± 4.65	.89
Angle (degrees)				
Level Walk	2.64 ± 0.55	2.51 ± 1.05	2.56 ± 0.69	.96
Narrow Walk	1.11 ± 0.62	1.47 ± 0.65	1.66 ± 0.49	.27
Narrow Walk + Count	1.36 ± 0.54	1.49 ± 0.62	1.74 ± 0.49	.47
Obstacle	2.07 ± 0.91	1.84 ± 0.66	2.56 ± 0.78	.26
Obstacle + Stroop	2.12 ± 0.61	2.14 ± 0.47	2.71 ± 0.50	.11
Rate of Response (responses/minute)				
Sit + Count	36.57 ± 9.98	33.75 ± 8.84	43.00 ± 18.96	.42
Narrow Walk + Count	34.00 ± 10.78	30.60 ± 7.43	39.67 ± 17.95	.41
VRT (ms)				
Sit + Stroop	941.15 ± 133.71	1137.25 ± 150.83	1025.85 ± 114.43	.06
Obstacle + Stroop	947.53 ± 159.47	1068.04 ± 120.12	984.89 ± 185.72	.37

Effect of Intervention

The results from the mixed-effects repeated-measures ANOVA showed that the group x time x testing condition interaction was not significant for the frontal plane COM-AJC inclination angle (P=.93, effect size=0.01 and P=.91, effect size=0.01 for narrow walking and obstacle crossing tasks, respectively), or for the rate of response for the counting backward by threes task (P=.34, effect size=0.11). However, the group x time x congruency x condition interaction was found to be significant for the verbal reaction time of the auditory Stroop task (P=.02, effect size=0.38). The following sections include analysis for each condition.

Narrow walking and obstacle crossing under single-task conditions

The group x time interaction was not significant for the frontal plane COM- AJC inclination angle, for either the narrow walking (P=.25, effect size=0.15) or obstacle crossing conditions (P=.86, effect size=0.02). However, the main effects of time was significant (P=.04, effect size=0.2 for narrow walking and P=.03, effect size=0.23 for obstacle crossing), indicating that participants in all groups demonstrated a significantly smaller angle after the training when performing narrow walking and obstacle crossing without additional cognitive tasks.

Counting backward by 3s task while sitting

There was a significant group x time interaction effect on the rate of response when the participants performed the counting backward by 3s task while sitting (P=.04,

effect size=0.29). Participants who received dual-task training (regardless of instructional set) demonstrated significant improvement on the cognitive task (i.e. counted faster) after the training (FP: P=.003, effect size=0.49, and VP: P=.02, effect size=0.36). However, no significant improvement was found for the ST group (P=.72, effect size=0.01).

Auditory Stroop task while sitting

A group x time x congruency interaction for VRT was not significant (P=.16, effect size=0.21). However, there was a significant group x time interaction effect (P=.02, effect size=0.37), indicating that the amount of improvement in VRT was different across training groups regardless of the congruency effect. Follow-up analyses revealed that the participants in the FP and VP groups responded significantly faster after the training (P=.003, effect size=0.54, and P=.01, effect size=0.41, respectively). However, there was no significant change after the training for the ST group (P=.75, effect size=0.01).

Narrow walking while counting backward by 3s (a practiced dual-task condition)

This condition was of most interest to us since it represented the balance performance under a practiced dual-task condition. The results from the repeated-measures ANOVA revealed a significant group x time interaction for the frontal plane COM and AJC inclination angle under the narrow walking task while counting backward by 3s (P=.04, effect size=0.31) (Table 3.2). This interaction indicated that, although the angle reduction was significant for all groups after the training, it was greater for the VP group than for the ST and FP groups (P=.02 and P=.03, respectively) (Figure 3.2).

Table 3.2. Findings on outcome measures at pre-training (Pre), and the End of training (Post) by intervention group.

Measure	Single-Task Balance Training (ST) (N = 7)		Dual-Task Training: Fixed Priority (FP) (N = 8)		Dual-Task Training: Variable Priority (VP) (N = 6)		P^*
	Pre	Post	Pre	Post	Pre	Post	
Angle (degrees)							
Narrow Walk	1.11±0.62	0.99±0.13	1.47±0.65	1.38±4.60	1.66±0.49	1.09±0.56	.25
Narrow Walk + Count	1.36±0.54	0.95±0.33	1.49±0.62	1.04±0.67	1.74±0.49	0.76±0.38	.04
Obstacle	2.07±0.91	1.74±0.69	1.84±0.66	1.64±0.32	2.56±0.78	2.20±0.66	.86
Obstacle + Stroop	2.12±0.61	1.85±0.51	2.14±0.47	2.09±0.75	2.71±0.50	2.33±0.82	.54
Rate of Response							
Sit + Count	36.57±9.98	37.43±6.08	33.75±8.84	42.69±7.29	43.00±18.96	51.00±19.54	.04
Narrow Walk +Count	34.00±10.78	32.57±6.40	30.60±7.43	36.75±6.32	39.67±17.95	51.80±20.55	.04
VRT (ms)							
Sit + Stroop	939.54±49.01	952.05±66.64	1104.18±38.75	974.48±52.68	1021.96±44.74	906.95±60.83	.02
Obstacle + Stroop	936.51±60.66	982.06±56.05	1026.83±47.96	1022.20±44.31	963.53±55.38	938.29±51.16	.21

* Group x time interaction effect.
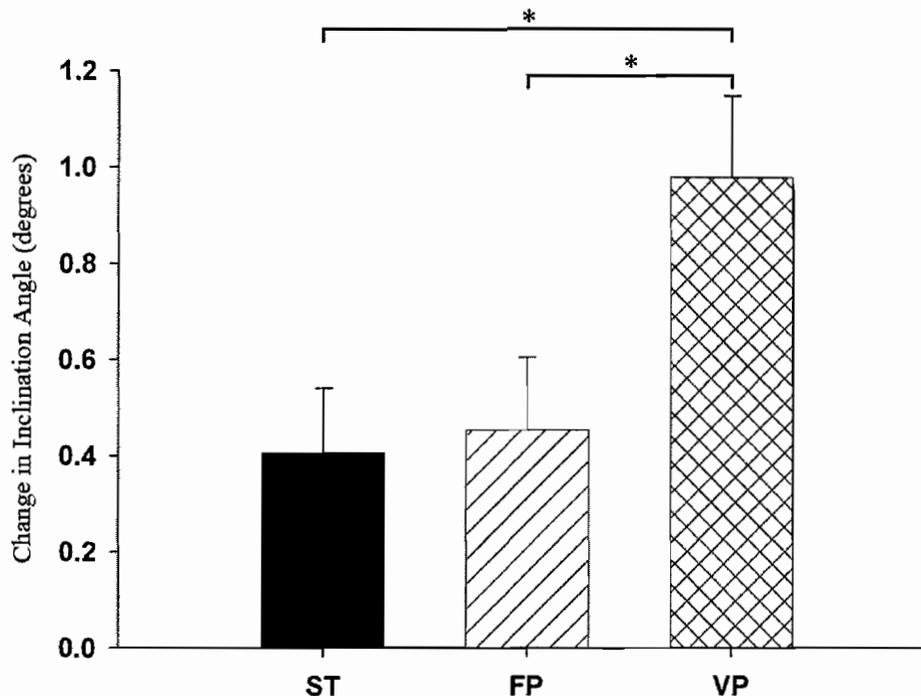
Figure 3.2. Bar graph of change (pre testing – post testing) on center of mass-ankle joint center inclination angle under a practiced dual-task condition (narrow walking while counting backward by 3s). Solid bar represents single-task balance training group (ST); lined bar represented dual-task training with fixed-priority instructions (FP); hatched bar represents dual-task training with variable-priority instructions (VP).

For the number of missteps, the group x time interaction was not significant (P=.11, effect size=0.22), resulting from the equivalent amount of improvement across all training groups. However, we found a significant main effect of time (P<.001, effect size=0.60), indicating that participants in all groups significantly reduced the numbers of misstep after training. Overall, the mean number of missteps was 6.4 before training and 1.9 after training, indicating a 4.5 reduction in the number of missteps (95% confidence interval = 2.7-6.3).

In addition, the group x time interaction was significant for rate of response (P=.04, effect size=0.28), indicating that only the VP group showed significant improvement (i.e. count backward by 3s faster) on narrow walking while counting backward by 3s after the training. Figure 3.3 demonstrated the rates of response under single-task and dual-task conditions. The number of errors participants made on the counting backward task was comparable across groups (P=.36, effect size=0.11).

Obstacle crossing with auditory Stroop task (a novel dual-task condition)

Neither the interaction nor main effects on the COM and AJC inclination angle were significant under the novel dual-task condition (P>.05) (Table 3.2). Similarly, a group x time x congruency interaction for VRT was not significant (P=.42, effect size=0.10). The only significance found for VRT data under this condition was the congruency main effect (P<.001, effect size=0.59), indicating that the verbal reaction time was longer in incongruent conditions than in congruent conditions.
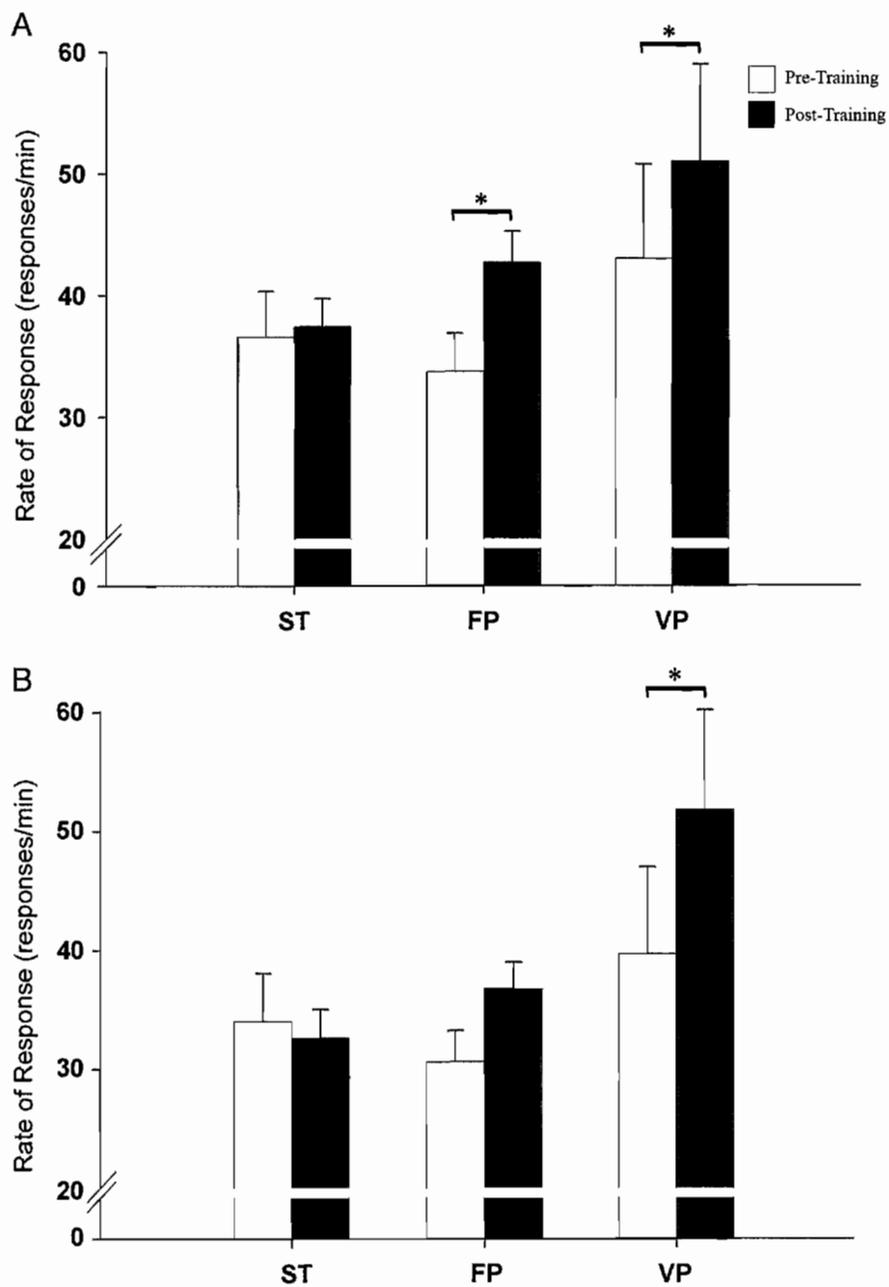
Figure 3.3. Mean rate of response at pre-training and post-training for a counting backwards by 3s task while sitting (A) and while performing narrow walking (B)

Discussion

The goal of this randomized controlled trial study was to compare the effects of three types of training on balance performance in both single- and dual-task (novel and practiced) conditions among older adults with impaired balance. Results indicated that type and magnitude of benefits vary by training type. Dual-task training with VP instructional set was more effective in improving both balance and cognitive performance under a dual-task condition than either the ST or the FP training strategies.

Participants in all training groups demonstrated significant improvement on balance performance under a practiced dual-task condition (narrow walking while counting backward by 3s), with the greatest improvement found in the VP group. The average angle reduction was about 1 degree for the VP group, compared to 0.4 degree for the ST and FP groups. A 1 degree change and a 0.4 degree change were associated with a 56% and 30% reduction in body sway, respectively. According to Lee and Chou,[68] the COM-COP inclination angle in the frontal plane is a sensitive measure to identify elderly people who are prone to fall, with a smaller angle indicating better balance performance. In their study, elderly patients with balance disorders demonstrated about 1.8 degree and 1.5 degree greater angles (or 45% and 37% larger body sway) than did healthy elderly under single-task level walking and obstacle crossing (10% body height) conditions, respectively.[68]

In addition to dual-task balance performance, the VP training strategy was also more effective at improving dual-task cognitive performance. Although both FP and VP groups demonstrated equivalent training benefits on single-task cognitive performance,

only the VP group showed significant improvement in cognitive performance under a dual-task condition. They significantly improved on the counting backward by 3s task (i.e. increased rate of responses) during narrow walking after training. Thus, the data from this study supported the findings from Kramer et al. that the VP training strategy offers a greater advantage over ST and FP training strategies on improving dual-task performance.[59]

There was a significant improvement on dual-task balance performance following both single-task and dual-task training. This finding was consistent with the prediction of the task automatization model and inconsistent with the prediction of the task integration model. Based on the task automatization hypothesis, the narrow walking task became automatized after practicing either under the single-task condition (practicing this task separately) or dual-task conditions (practicing this task together with additional cognitive tasks).[60,61] As a result, the processing demand required to perform the narrow walking task was reduced, leading to the rapid development of skills. Thus, both the single- and dual-task training led to improved balance under dual-task conditions. This finding did not support the task integration model, which proposed that dual-task training is necessary to the efficient integration of the two tasks, and thus a critical factor in improving dual-task performance.

The improvement in dual-task balance performance after single-task balance training could not be accounted for, in its entirety, by automatization of the single task. If task automatization was the only mechanism underlying the improvement in dual-task balance performance, the magnitude of training benefits should be comparable across

training groups. Although participants in all groups spent the same amount of time in training, the actual number of narrow walking trials practiced by the ST group exceeded that of the dual-task training group, because adding a secondary task slowed gait speed resulting in fewer practice trials in the equivalent amount of time. Despite fewer practice trials, the VP training group improved to a greater extent than the ST group. Thus, results suggest that improvement on dual-task performance might be the result of both automatization of an individual task and the development of task coordination skills. Participants in the VP group may have learned to efficiently coordinate performance between the two tasks (task integration) as they improved performance on each task (task automatization).[59]

To assess the generalizability of dual-task processing skills, the participants were asked to perform a novel dual task (i.e. obstacle crossing with auditory Stroop task) before and after training. Unlike Kramer and colleagues, we did not find that dual-task processing skills acquired during training transferred to a novel dual task. While all groups improved performance on the narrow walking task while counting backward by 3s, none improved on the novel obstacle crossing task with auditory Stroop task. Similarly, even though the VP group showed a significant improvement on cognitive performance (counting backward by 3s) under a practiced dual-task condition, this benefit was not transferred to the cognitive task (auditory Stroop task) under a novel dual-task condition. One possible explanation for this lack of transfer was that the walking tasks used for the practiced task (narrow walking) and the novel task (obstacle crossing) were quite different. Specifically, only one perturbation/obstacle was used for

the obstacle crossing task whereas continuous perturbations were employed for the narrow walking task. Another possible explanation is that dual-task balance processing skills can be transferred to novel tasks; however, more time is needed to observe this transfer effect in elderly people.[59]

Although this study provided some interesting data regarding the efficacy of dual-task training in balance control, a number of unanswered questions remain. First, the extent to which the participants would benefit from practicing a cognitive task in isolation is not known. Second, further research is needed to evaluate the relative efficacy of different intensities and durations of training, as well as retention of skills. Third, since the group x time x testing condition interaction was not significant for any of the outcomes measured; it was not clear whether the benefits of VP training found in this study were specific to balance performance under dual-task conditions. With enough statistical power, we might also observe the similar training effect on single-task balance performance. Finally, even though Lee and Chou[68] demonstrated that the frontal plane inclination angle is sensitive to identify elderly fallers, there are no data in the literature linking these laboratory measures to actual fall risk.

In summary, this is the first randomized controlled trial to examine the mechanisms underlying training-related changes in dual-task balance performance of older adults with impaired balance. The results of this study suggest that a VP training strategy was more effective in improving both balance and cognitive performance under a dual-task condition than the ST and FP training strategies. However, the dual-task balance processing skills acquired during training did not generalize to a novel dual-task

condition. Finally, the overall data do not completely support either the task automatization or the task integration models in isolation. Rather, as suggested by Kramer and colleagues, results suggest that the benefits acquired during VP training were the result of both automatization of the single task and the development of task integration skills.

Bridge

Chapter III investigated the efficiency of three different training strategies in an effort to understand the mechanisms underlying training-related changes in dual-task balance performance of older adults with balance impairment. Chapter IV summarizes the general discussion and conclusions from all of the studies in this series.

CHAPTER IV

DISCUSSION AND CONCLUSION

The goal of this randomized controlled trial study was to evaluate the effectiveness of individualized training programs on dual-task balance performance in older adults with balance impairment. In particular, the efficacy of three different training strategies was examined in an effort to gain a better understanding of training-related changes in dual-task balance performance. Several important findings were obtained in the present study.

This study provides evidence that a traditional rehabilitation program emphasizing training balance under single-task conditions may not be effective in improving balance control during dual-task contexts in older adults with balance impairment. It was found that although our single-task training program was effective in improving single-task balance performance, it was not effective in improving balance performance under dual-task conditions. Specifically, when a cognitive task was added, only participants who received dual-task training walked significantly faster after the training.

In addition, the findings clearly suggest that older adults with balance impairment can improve their balance performance under dual-task conditions through training. After practicing balance activities in the dual-task settings, elderly persons demonstrated improvements in gait speed under dual-task conditions. They walked significantly faster while simultaneously performing a cognitive mathematics task. Because a number of studies have shown that slow gait speed under dual-task conditions was associated with high risks for multiple falls[12] as well as poor executive function,[15] our dual-task training programs have the potential to reduce falling rate and functional decline in elderly people.

Moreover, explicit instruction regarding attentional focus is found to be an important factor for improvement in dual-task balance performance. In particular, the variable-priority instructional set (VP) offers advantages over the fixed-priority instructional set (FP) in terms of the degree of improvement, the rate of learning, and the retention of dual-task training benefits. Although participants in all training groups demonstrated significant improvement on balance performance under dual-task conditions, the VP group improved to a greater extent than the FP group after training. The average reduction in the inclination angle (angle between the line connecting the COM and ankle joint center (AJC) and a vertical line through the AJC, a measure of stability) was about 1 degree for the VP group, compared to 0.4 degree for the FP group when individuals were performing the tasks of walking with a narrow base of support and counting backwards by three. Because it has been shown that the inclination angle in the frontal plane is a sensitive measure to identify elderly people who are prone to fall,[68] the

findings on the inclination angle confirm the results that the dual-task training programs, especially with VP instruction, might be effective in reducing the risk of falling in the elderly population.

To examine the interim balance changes during training and retention of the training effect, selected test were repeated after the second week of training and at twelve weeks following the end of training, respectively. It was found that only participants who received dual-task training with VP instructions demonstrated significant improvements on gait speed under dual-task conditions at the end of the 2nd week of training and this training benefit was maintained after 12 weeks of training. Thus, these findings suggested that the instruction regarding attentional focus was an important factor contributing to the rate of learning, and the retention of dual-task training benefits.

This study also showed that only the participants in the single-task balance training group increased their self-reported confidence when performing daily activities. One possible explanation for this finding is that the activities (balance + cognitive tasks) we gave to the participants in the dual-task training groups were much more difficult than the tasks (only balance tasks) given to the participants in the single-task training group. As a result, the balance skills of the participants in the dual-task training groups were continually challenged and this may have resulted in a reduced confidence in performing daily tasks. It is also possible that changes in cognitive constructs such as confidence and self-efficacy do not change at the same rate as physical function. Further research is necessary to understand this finding.

In addition, we found that it was feasible to implement individualized dual-task training, combining a traditional task-oriented intervention with a variety of cognitive tasks, in community-dwelling elderly using existing resources such as exercise balls, cards, games, and facilities that have enough space to offer exercise programs. The participants in this study could in fact adhere to the instructional sets regarding attentional focus. They successfully allocated their attention to the task to which they were instructed (the average percent of success was 80%). Thus, results may generalize to similar population, excepting those with significant neurological or musculoskeletal problems.

To assess the generalizability of dual-task processing skills, the participants were asked to perform a novel dual task (i.e. obstacle crossing with auditory Stroop task) before and after training. Unlike Kramer and colleagues, we did not find that dual-task processing skills acquired during training transferred to a novel dual task. While all groups improved performance on the narrow walking task while counting backward by 3s, none improved on the novel obstacle crossing task with auditory Stroop task. One possible explanation for this lack of transfer was that the walking tasks used for the practiced task (narrow walking) and the novel task (obstacle crossing) were quite different. Specifically, only one perturbation/obstacle was used for the obstacle crossing task whereas continuous perturbations were employed for the narrow walking task. Another possible explanation is that dual-task balance processing skills can be transferred to novel tasks; however, more time is needed to observe this transfer effect in elderly people.[59]

Because the three-way (group x time x testing condition) interaction was far from reaching significance for all outcome measures, it was not clear whether the training effect found in this study was specific to balance performance under dual-task conditions. With enough statistical power, we might observe a similar training effect on single-task balance performance as well. Specifically, the type of training might not be only crucial for improvement in dual-task balance performance but also important for improvement in balance performance under single-task contexts. Dual-task training programs, which were found to be effective in improving dual-task balance performance, might also be superior to traditional single-task training in improving single-task balance performance.

Our results provide empirical evidence to support other dual-task training studies that have focused on healthy young adults and patients with stroke. Research by Pellecchia demonstrated that dual-task training was superior to single-task training in improving dual-task balance performance in healthy young adults (aged 18-46 years).[58] In Pellecchia's study, participants in the single-task training group practiced the balance task (quiet standing on the foam pad) and the cognitive task (counting backward by threes) separately whereas participants in the dual-task training group were required to perform both tasks concurrently. The results showed that postural sway under dual-task conditions (as measured by the total distance traveled by the center of pressure) decreased after dual-task training.

Similarly, work by Yang et al[62] has also shown the positive effect of dual-task training program on balance performance in patients with chronic stroke (aged 45-80 years). However, unlike our study and Pellecchia's study where the single-task training

group served as the control group, participants in Yang et al's control group did not receive any training. In addition, only motor tasks, not cognitive tasks, were used during training in their study. Participants in the dual-task training group in their study received ball exercise training such as walking while holding a ball, walking while kicking a ball, and walking while bouncing a ball. Thus, it is still unclear whether the type of task (motor vs. cognitive) that is performed concurrently with the balance tasks in the exercise programs affects the type and magnitude of training benefits on dual-task balance performance. None of the studies have examined the effect of dual-task training or the effect of instructional set on dual-task balance performance in the elderly population.

Finally, because participants benefited to a greater extent with VP training than with other types of training, we agreed with Kramer et al.'s notion that efficient improvement on dual-task performance was the result of both automatization of an individual task and the development of task coordination skills.[59] If task automatization was the only mechanism underlying the improvement in dual-task balance performance, the magnitude of training benefits should be comparable across training groups. Similarly, if the efficient integration of the two tasks was the only mechanism underlying changes, the magnitude of training benefits acquired during FP training should be equivalent to those acquired during VP training. Since this was not the case, it indicates that VP training is the most effective strategy to improve dual-task balance performance; participants in the VP group may have learned to efficiently coordinate performance between the two tasks (task integration) as they improved performance on each task (task automatization).[59]

Strengths of the Study

This study was a double-blind, randomized controlled trial study, one of the strongest designs to evaluate cause and effect relations.[88] The study design has several important features including, 1) the random allocation of participants to intervention groups, 2) both the testers and the participants being blinded from group assignments and from the randomization procedure, 3) all intervention groups being treated identically except for the experimental treatment, and 4) data being analyzed using intention-to-treat analysis (analysis that compares participants in the groups to which they were randomly assigned). With all these features, it ensures no systemic differences between intervention groups (except for the experimental treatment) and ensures no systemic bias toward the assessment of outcomes, subsequently giving the most accurate results.

In addition, this was the first study to evaluate the effectiveness of traditional rehabilitation programs on dual-task balance performance and to determine the relative efficacy of different training strategies in an effort to better understand the mechanisms underlying training-related changes in dual-task balance performance in elderly individuals with balance impairment.

Limitations of the Study

Although this study provided some interesting findings regarding the efficacy of dual-task training in balance control, a number of unanswered questions remain. First, the extent to which the participants would benefit from practicing a cognitive task in

isolation is not known. Second, the small sample size in the study may have limited the statistical power to detect the dual-task training effect on single-task balance performance. Third, although all outcome measures were found to have no significant difference between groups at baseline, the fact that participants in the single-task training group walked with a faster gait speed and a smaller inclination angle at the beginning of training may have limited the training effect for this population. Finally, even though the primary outcome measures used in this study (i.e. gait speed and inclination angle) have been shown to be sensitive to identify elderly fallers, there are no data in the literature linking these measures to actual fall risk.

Directions for Future Research

The effectiveness of individualized training on dual-task balance performance needs further study. The findings from the present study suggest that type of training is an important factor in improving balance performance under dual-task conditions. In particular, dual-task training with variable-priority instruction seems to offer advantages over the other training strategies. However, these findings need to be confirmed by a larger study.

Further research is also needed to evaluate the extent to which the participants can benefit from practicing a cognitive task in isolation. In addition, the relative efficacy of different intensities and durations of training, as well as retention of skills need further investigation. Moreover, since this study showed that only the participants in the single-task balance training group increased their self-reported confidence when performing

daily activities, further research is necessary to understand this finding. Lastly, the effectiveness of this individualized training on fall risk in elderly people and other vulnerable populations should be examined.

APPENDIX A

LETTER TO PHYSICIANS

Open letter to physicians:

The following person,_____, DOB
_____ is under your care and is interested in volunteering as a subject in a study being conducted at the Motor Control Lab at the University at Oregon on how older adults perform balance tasks while engaged in secondary tasks. He/she has given us your name as their primary care physician and has signed an informed consent allowing us to contact you on their behalf. We are asking for you to recommend the inclusion or exclusion of the above person based their medical history and description of the study enclosed.

The experimental procedures may include one of the following:

1. They may be asked to walk along a 30 foot walkway, step over an obstacle, and continue walking along the walkway, all at a comfortable self-selected speed while barefoot. The heights of the obstacle correspond to those ordinarily encountered during daily activities, ranging from the height of a door threshold (2.5% ≈ 4cm) to the height of a standard step (10% ≈ 18cm). They may be asked to perform a second task while walking over the obstacle. The second auditory task will consist of listening to the words high, spoken at a high or a low tone, and low, spoken at a high or a low tone, in random order. They will have to report "high" or "low" to questions regarding those presented tones as quickly as possible.

2. They may be asked 1) to remain balanced while standing in Tandem Romberg (with one foot in front of the other) for 30 seconds on a force plate; 2) to perform a visual reaction time task or a visual or auditory memory task by itself (for example, remembering the location or shape of objects, or the pitch or location (Left or Right) or 3) to perform both tasks together. When performing the tasks together we will ask them to focus primarily on the balance task or on the spatial task.

3. They may be asked to do the same experiments above, but while walking down the walkway. When they step on the platform, it may move forward, simulating a slip.

4. They may be asked to walk down the walkway, as described above, but, in some trials

the secondary task may be presented in easy vs a hard version. (for example, we will ask you to listen the word "high", spoken at a low tone) and in other cases the walking task will be made easy (normal walking) vs hard (stepping over different heights of the obstacle)

5. They may be asked 1) to walk between two strips of tape secured to the floor that ran parallel the length of the walkway; 2) to count backward by 3s from any starting number from 90-200; or 3) to perform both tasks together.

6. They may be asked to be part of a training program. They will participate in 45 minute retraining sessions three times a week for four weeks (e.g. standing on a tilt board, lifting objects, leaning over to pick up objects from lower surfaces, stepping up onto a stool, standing with a small base of support, stepping over obstacles). If they are in the first experimental group they will have balance retraining under single task conditions (doing one thing at a time). If they are in the second and third experimental groups they will participate in the same set of balance activities, but will perform these drills while simultaneously performing a variety of secondary tasks (for example, math tasks (counting backwards) and verbal tasks such as sentence completion or remembering words in a specific category). Lastly, if they are in the fourth experimental group they will participate in the attention training under dual-task conditions (e.g. counting backward by 3s while simultaneously performing a visual identification task).

Rest period will be provided as needed. An experimental session will last about one and a half hours. We want to provide as broad an opportunity as possible for participation. However, both for reasons related to risk and experimental design, subjects with significant or unstable cardiovascular, orthopedic, or other neurological involvement must be excluded. Please indicate on the medical clearance sheet (separate page) if there is any reason from your record of medical history or physical examinations the above-named individual should or should not participate in this study.

This sheet is yours to keep for the patients chart. Please just fax back the medical clearance.

Thank you for your time and consideration.

Sincerely,

Marjorie Woollacott, PhD

University of Oregon
College of Arts and Sciences
Department of Human Physiology
Motor Control Laboratory

MEDICAL CLEARANCE FOR PARTICIPATION

PLEASE FAX TO : <u>346-4595</u>

TO: <u>Marjorie Woollacott/ Patima Silsupadol</u>

LOCATION: <u>Motor Control Lab at the University of Oregon</u>

FROM: _____

LOCATION: _____

PARTICIPANT'S NAME:_____ DOB_____

Please exclude the participant if they have any of the following:

    ____Uncontrolled or unstable cardiovascular disease
    ____Significant respiratory compromise (COPD)
    ____Neurological disease- new diagnosis in the last year
    ____Significant orthopedic involvement (amputation; kyphosis, severe OA or RA)
    ____Orthopedic surgery to the lower extremities in the last year
    ____Cancer-active
    ____Uncontrolled Diabetes or Diabetic Neuropathy
    ____End Stage Renal Disease
    ____Incontinence of Bowel and Bladder
    ____Peripheral Vascular Disease
    ____Mental Illness
    ____Other:_____

If you have any questions or concerns, please call (541)346-0275 or 346-4144.

can participate ☐   **cannot** participate ☐

Physician Comments:_____

Signature_____ Date_____

THANK YOU for your timely response!!

APPENDIX B

MINI MENTAL STATE EXAMINATION (MMSE)

Name: _____   DOB: _____

Date: _____

		Points	Scores

Orientation

1. What is the year?   1   ____
    What is the season?   1   ____
    What is the date?   1   ____
    What is the day?   1   ____
    What is the month?   1   ____

2. What state of America are we in?   1   ____
    What Country are we in?   1   ____
    What city are we in?   1   ____
    What building are we in?   1   ____
    What floor are we on?   1   ____

Registration

3. I am going to name three objects. After I have said them please repeat them.
    Remember what they are because I am going to ask you to name them in a few
    minutes.

    APPLE : TABLE : PENNY   APPLE   1   ____
                                       TABLE   1   ____
    Code first attempt then repeat the answers until   PENNY   1   ____
    The subject learns all three.

Attention and Calculation

4. Can you subtract 7 from 100, and then subtract   93   1   ____
    7 from that, and keep subtracting 7 until I have you stop.   86   1   ____
                                                         79   1   ____
                                                         72   1   ____
                                                         65   1   ____

5. I am going to spell a word forwards and I want   D   1   ____

you to spell it backwards. The word is WORLD,   L   1   ____

W-O-R-L-D. Now spell it backwards.   R   1   ____

    O   1   ____

    W   1   ____

Recall

6.   Now what were the three objects I asked you to remember   APPLE 1   ____

    TABLE 1   ____

    PENNY 1   ____

Language

7.   Interviewer: Show watch. What is this called?   1   ____

    Interviewer: Show Pen. What is this called?   1   ____

8.   I'd like you to repeat this phrase after me:

    " NO IFS ANDS OR BUTS"   1   ____

9.   Read the words on this page and do what it says   1   ____

CLOSE YOUR EYES!

10. Interviewer: Read the full statement below before handing respondent a blank piece of paper. Do not repeat or coach.

I am going to hand you a piece of paper. When I do, take the piece of paper in your right hand, fold the paper in half with both hands, and put the paper down in your lap.

    Takes paper in right hand   1   ____

    Folds paper in half   1   ____

    Puts paper down in lap   1   ____

11.   Write and complete sentence on this piece of paper for me. Sentence should have a subject and a verb and make sense. Spelling and grammatical errors are OK.   1   ____

12. Here's a drawing. Please copy the drawing on the same paper.
Interviewer: Hand drawing to respondent. Correct if 2 convex
five-sided figures and intersect makes a four-sided figure.   1   ____
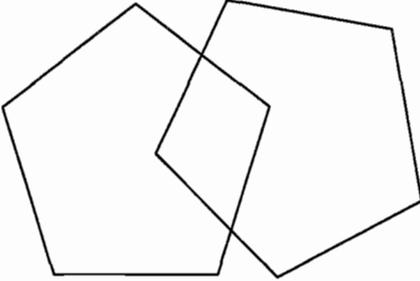
TOTAL SCORE   _____
Score best of either # 4 or 5 to give a
total out of 30 points.

Date ____ _____

APPENDIX C

INFORMED CONSENT

AGE-RELATED CHANGES IN POSTURE AND MOVEMENT

The Effect of Single- vs. Dual-Task Training on Balance Performance in Older Adults

University of Oregon

You are invited to participate in a research study being conducted by Dr. Marjorie Woollacott in the Department of Human Physiology of the University of Oregon. As a result of the study we hope to learn more about how older adults recover from trips and slips while standing and walking (obstacle avoidance) and why some older adults have problems balancing. The results from this study will contribute to a better understanding of balance control during walking. This knowledge can provide insight into the development of appropriate training protocols to assist persons with balance problems.

If you decide to participate, you must first receive medical clearance from your physician to participate in the study. By signing this consent form you will allow us to send your physician the accompanying letter, asking for medical clearance for participation in the study. In addition, as part of the study you will be examined by a physical therapist and a neurologist. The screening tests include a health survey questionnaire, as well as physical, neurological, and Mini-mental examinations. These examinations will be performed at no charge to you. The screening procedure will take two 45-minute sessions. This means that you will need to come to the Motor Control Lab of the University of Oregon twice for screening. The first screening will include the health survey and physical examination. A health survey form will be presented to you to fill out. The physical examination will be conducted by a physical therapist. In the second screening, a neurologist will examine your neurological and mental functions. Both screening sessions will be videotaped for later review. You need to pass all of the screening items to participate in the experimental portion of this study.

Upon successful completion of the screening tests and with your continued willingness to participate, a third visit to the Motor Control Lab or Motion Analysis Lab will be scheduled. During this third visit, you will be asked to participate in one or more of the following **testing**:

1. You will be asked to walk along a 10-m walkway, step over an obstacle, and continue walking along the walkway, all at a comfortable self-selected speed while barefoot. The heights of the obstacle correspond to those ordinarily encountered during daily activities, ranging from the height of a door threshold (2.5% ≈ 4cm) to the height of a standard step (10% ≈ 18cm). You may be asked to perform a second task while walking over the obstacle. The second auditory task will consist of listening to the words high, spoken at a high or a low tone, and low, spoken at a high or a low tone, in random order. You will have to report "high" or "low" to questions regarding those presented tones as quickly as possible.

2. You may be asked 1) to remain balanced while standing with one foot in front of the other for 30 seconds on a force plate; 2) to perform a visual reaction time task or a visual or auditory memory task by itself (for example, remembering the location or shape of objects, or the pitch or location (L or Rear); or 3) to perform both tasks together. When performing the tasks together we will ask you to focus primarily on the balance task or on the second task.

3. You may be asked to do the same experiments above, but while standing on or walking down the walkway. When you step on the platform, it may move forward or backward, simulating a slip.

4. You may be asked to walk down the walkway, as described above, but, in some trials the secondary task may be presented in easy vs a hard version. (for example, we will ask you to listen the word "high", spoken at a low tone) and in other cases the walking task will be made easy (normal walking) vs hard (stepping over different heights of the obstacle)

5. You may be asked 1) to walk between two strips of tape secured to the floor that ran parallel the length of the walkway; 2) to count backward by 3s from any starting number from 90-200; or 3) to perform both tasks together.

Balance Training Program

Upon successful completion of the laboratory session and with your continued willingness to participate, you will be asked to participate in 45 minute balance retraining sessions three times a week for four weeks either inside or outside the Motor Control Lab (e.g. standing on a tilt board, lifting objects, leaning over to pick up objects from lower surfaces, stepping up onto a stool, standing with a small base of support, stepping over obstacles). If you are in the first experimental group you will have balance retraining under single task conditions (doing one thing at a time). If you are in the second and third experimental groups you will participate in the same set of balance activities, but will perform these drills while simultaneously performing a variety of secondary tasks (for example, math tasks (counting backwards) and verbal tasks such as sentence completion or remembering words in a specific category). Lastly, if you are in the fourth experimental group you will participate in the attention training under dual-task conditions. For example, you might be asked to counting backward by 3s while simultaneously performing a visual

identification task. For the counting backward by 3s, you will be asked to count backward by 3s from any starting number from 90-200. The visual task is to identify whether the alphabet presented on the computer screen is in the first half (A – M) or in the second half (N-Z) of the alphabets.

In some of the above laboratory sessions the way you respond to the disturbances of balance introduced by the platform may be measured by small disc sensors covered with hypoallergenic gel and placed on the surface of the skin over selected leg and trunk muscles. The skin areas over these muscles may be shaved and rubbed with an alcohol swab before the application of these sensors. Signals collected from these sensors will be recorded by a computer. We will also videotape your motion in each trial. Several markers may also be placed on your joints and some body landmarks to help identify joint movement in later videotape analysis. You will be asked to wear shorts and sleeveless t-shirts so that the markers can be observed clearly. You will also be asked to wear the harness we provide to guard against falling.

A rest period of 3 to 5 minutes will be provided 2-3 times during the sessions. Longer rest time will be offered if needed. Experiments will last about one and a half hours.

There is essentially no risk in the screening tests. All of the screening tests are similar to the routine examinations used in most physical therapy or neurology clinics. There is a minimal risk that you may fall when your balance is disturbed while walking across the platform. This risk is minimized by starting with small and slow platform movements, by your wearing a harness connected to an overhead support, by providing you a handrail to grasp all along the walkway, and by keeping an attendant near you while you are walking down the walkway. The harness will prevent you from falling to the floor in case you trip or slip. There is a minimal risk that you may fall while you are in the training program (for example, while lifting objects, leaning over to pick up objects from lower surfaces, stepping up onto a stool, standing with a small base of support, stepping over obstacles). This risk is minimized by using typical tasks of daily living, keeping an attendant near you during the training program, by providing you a handrail to grasp, by providing you a treatment belt that is used in rehabilitation centers, and by providing you a safe environment (free from unnecessary objects and distractions) suitable for training. The risk of getting a skin response to the application of sensors will be minimized by using hypoallergenic gel and tape. The incidence of a skin response to the gel and tape is actually low or non-existent. There is another risk that you may become tired or uncomfortable during some of the tasks. This risk is minimized by simply stopping the test at your request. There is also a risk of losing confidentiality of information. This will be minimized by coding all data with letters and numerals and keeping all participants' names on a separate sheet, which will be kept in the investigator's file.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. We may wish to use the video tape recording of your movements for educational purposes in

the future; however, your identity will not be disclosed. If you would like to give your permission at this time for use of this tape record for educational purposes, please place your initials by "yes". If you do not wish to give permission at this time, please place your initials by "no".

yes_____   no_____

Since your participation is voluntary, your decision as to whether or not to participate will not affect your relationship with the Motor Control Lab. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

Benefits from participation in this project include receiving free physical, neurological, and mental function examinations. **Reimbursement ($10.00 per visit) will be given for only completing the screening and experimental sessions. No reimbursements will be given for the training program.** We will also provide you with information on your postural responses and test results if we detect that you have balance problems.

You or your own insurer is responsible for any medical expenses resulting from injuries to you caused by your participation in this research project. If you have any questions about the research at any time, please feel free to contact Dr. Marjorie Woollacott at 346-4144. If you have questions regarding your rights as a research subject, contact the Human Subjects Compliance Office, University of Oregon, Eugene, OR 97403, (541) 346-2510. You will be offered a copy of this form to keep.

Your signature below indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you will receive a copy of this form, and that you are not waiving any legal claim, rights or remedies.

Signature _____ Date _____

Print Name_____

Name of your physician_____ _____

Address of physician_____ _____

APPENDIX D

HEALTH SURVEY QUESTIONNAIRE

Date of Test: _____

Subject Name: _____ Gender: M   F

Date of Birth: _____ Subject Phone: _____

Subject Address: _____ _____

Living Environment:
☐ Retirement Center   ☐ Private Home   ☐ Others_____

Ethnic Category: ☐ Hispanic or Latino   ☐ Not Hispanic or Latino

Racial Categories:
☐ American Indian/Alaska Native   ☐ Asian
☐ Native Hawaiian or Other Pacific Islander   ☐ Black or African American
☐ White   ☐ More Than One Race   ☐ Unknown or Not Reported

Body Height (ft): _____   Foot Preference: L   R
Body Weight (lb): _____   Foot Length: (L) _____
                                        (or Shoes size) (R) _____
General Health: _____
Daily Activities (Such as Walking, cycling, swimming):

    Type   _____

    Frequency (/week)   _____
    Duration (/time)   _____

Medical History:

1. Do you have or have you ever had the following (Y/N)? If yes, please indicate when, what, or in what situations:

_____ Loss of consciousness, convulsion, or seizure.

       If yes, when_____

_____ Neurological disease, eg., stroke, paralysis, numbness, Parkinson's

       disease, etc. If yes, what_____ and when

       _____

_____ Orthopedic disease, such as arthritis, back pain, fracture, etc.

       If yes, what_____ and when _____

_____ Heart problems, eg., high blood pressure.

       If yes, what _____

_____ Lung problems, eg., difficulty in breathing.

       If yes, what _____

_____ Dizziness, or tinnitus. If yes, when_____

_____ Visual problem. If yes, what_____

_____ Hearing loss

_____ Uncontrollable movement. If yes, what _____

_____ Difficulty with coordination of arms or legs.

       If yes, what kind of movement_____

_____ Difficulty with balance.

       If yes, in what situation _____

       and the number of trip, slip, or falls in the last 12 months_____

_____ Difficulty standing for 20-30 minutes with short period of rest

_____ Difficulty in walking. If yes, in what condition _____

_____ Do you use a cane or walker?

_____ Difficulty in speaking

_____ Diabetes

_____ Other medical problems?

If yes, what_____ _____ _____

2. Are you on any medications? What is the dosage? Do you experience any side effects?

3. Are you currently being treated for any medical problems?

Fall/Imbalance History:

1. How many falls have you experienced in the past year?
   a. No falls
   b. 1-2 times in the past year
   c. 1-2 times in the past six months
   d. More than 2 times in the past year

   If you circled "no fall", skip to question 3

2. When your most recent fall?_____
   Did the fall occur indoors or outdoors_____
   How did the fall occur?_____
   Did you feel dizzy when you fell?_____
   Were there any injuries from the fall?_____

3. How often do you trip, slip, stumble, or lose your balance?
   a. No history of imbalance
   b. Imbalance once a year
   c. Imbalance once a month
   d. Imbalance once a week
   e. Imbalance once a day

4. How did the imbalance occur?_____

APPENDIX E

TIMED 10-METER WALK TEST

Session_____

Name_____**Date**_____

Date of Birth_____**Height**_____

Each subject will be asked to walk for 10 m (33 feet) at a comfortable and maximum gait speed. Only the *middle 6m*, however, will be timed to eliminate the effects of acceleration and deceleration. Start and stop of performance time coincide with the toes of the leading foot crossing the 2-m mark and the 8-m mark, respectively

The comfortable gait speed: **Walk at their normal comfortable (natural) speed.**
The maximum gait speed: **Walk as quickly as they safely can without running.**

Practice (1 time): 10-Meter Walk
Practice: Mathematic task

1. **Single-task**: Comfortable gait speed

Time_____   Number of steps_____

2. **Single-task**: Maximum gait speed

Time_____   Number of steps_____

3. **Dual-task$_{manual}$**: Maximum gait speed

Time_____   Number of steps_____

4. **Dual-task$_{manual}$**: Comfortable gait speed

Time_____   Number of steps_____

5. **Dual-task$_{cognitive}$**: Comfortable gait speed

Time_____   Number of steps_____

6. **Single-task:** Maximum gait speed

Time_____   Number of steps_____ _____

7. **Dual-task$_{cognitive}$:** Maximum gait speed

Time_____   Number of steps_____ _____

8. **Dual-task$_{cognitive}$:** Comfortable gait speed

Time_____   Number of steps_____ _____

9. **Dual-task$_{manual}$:** Maximum gait speed

Time_____   Number of steps_____

10. **Single-task:** Comfortable gait speed

Time_____   Number of steps_____

11. **Dual-task$_{manual}$:** Comfortable gait speed

Time_____   Number of steps_____

12. **Dual-task$_{cognitive}$:** Maximum gait speed

Time_____   Number of steps_____

APPENDIX F

BERG BALANCE SCALE

Name _____   Date: _____

Grading: Please mark the lowest category that applies.

1. Sitting to standing
   Instruction: Ask the patient to please stand up. Try not to use hands for support.
   (4) able to stand, no hands and stabilize independently
   (3) able to stand independently using hands
   (2) able to stand using hands after several tries
   (1) needs minimal assist to stand or to stabilize
   (0) needs moderate or maximal assist to stand   _____

2. Standing unsupported
   Instruction: Stand for 2 minutes without holding on to any external support.
   (4) able to stand safely 2 minutes
   (3) able to stand 2 minutes with supervision
   (2) able to stand 30 seconds unsupported
   (1) needs several tries to stand 30 seconds unsupported
   (0) unable to stand 30 seconds unassisted   _____

IF SUBJECT IS ABLE TO STAND 2 MINUTES SAFELY, SCORE FULL MARKS
FOR SITTING UNSUPPORTED. PROCEED TO POSITION CHANGE STANDING
TO SITTING.

3. Sitting unsupported feet on floor
   Instruction: Sit with arms folded for 2 minutes.
   (4) able to sit safely and securely 2 minutes
   (3) able to sit 2 minutes under supervision
   (2) able to sit 30 seconds
   (1) able to sit 10 seconds
   (0) unable to sit without support 10 seconds   _____

4. Standing to sitting

Instruction: Please sit down.

(4) sits safely with minimal use of hands

(3) controls descent by using hands

(2) uses back of legs against chair to control descent

(1) sits independently but has uncontrolled descent

(0) needs assistance to sit _____

5. Transfers

Instruction: Please move from a chair with arm rests to a chair without arm rests and back again.

(4) able to transfer safely with only minor use of hands

(3) able to transfer safely with definite need of hands

(2) able to transfer with verbal cueing and/or supervision

(1) needs one person to assist

(0) needs two people to assist or supervise to be safe _____

6. Standing unsupported with eyes closed

Instruction: Close your eyes and stand still for 10 seconds.

(4) able to stand 10 seconds safely

(3) able to stand 10 seconds with supervision

(2) able to stand 3 seconds

(1) unable to keep eyes closed 3 seconds but stays steady

(0) needs help to keep from falling _____

7. Standing unsupported with feet together

Instruction: Place your feet together and stand without holding on to any external support.

(4) able to place feet together independently and stand 1 minute safely

(3) able to place feet together independently and stand 1 minute with supervision

(2) able to place feet together independently but unable to hold for 30 seconds

(1) needs help to attain position but able to stand 15 seconds with feet together

(0) needs help to attain position and unable to hold for 15 seconds _____

THE FOLLOWING ITEMS ARE TO BE PERFORMED WHILE STANDING UNSUPPORTED

8. Reaching forward with outstretched arm

Instruction: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. Examiner places a ruler at end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward leaning position.

(4) can reach forward confidently >10 inches
(3) can reach forward >5 inches safely
(2) can reach forward >2 inches safely
(1) reaches forward but needs supervision
(0) needs help to keep from falling   _____

9. Pick up object from the floor

Instruction: Pick up the shoe/slipper that is placed in front of your feet
(4) able to pick up slipper safely and easily
(3) able to pick up slipper but need supervision
(2) unable to pick up but reaches 1-2 inches from slipper and keeps balance independently
(1) unable to pick up and needs supervision while trying
(0) unable to try - needs assist to keep from falling   _____

10. Turning to look behind over left and right shoulders

Instruction: Turn to look behind you over your left shoulder. Repeat to the right.
(4) looks behind from both sides and weight shifts well
(3) looks behind one side only, other side shows less weight shift
(2) turns sideways only but maintains balance
(1) need supervision when turning
(0) needs assist to keep from falling   _____

11. Turn 360 degrees

Instruction: Turn around in a full circle, then turn a full circle in the other direction.
(4) able to turn 360 safely in <4 seconds each side
(3) able to turn 360 safely one side only in <4 seconds
(2) able to turn 360 safely but slowly
(1) needs close supervision or verbal cueing
(0) needs assistance while turning   _____

12. Count number of times step stool is touched

Instruction: Place each foot alternately on the stool. Continue until each foot has touched the stool
four times for a total of eight steps.
(4) able to stand independently and safely and complete 8 steps in 20 seconds
(3) able to stand independently and complete 8 steps in >20 seconds
(2) able to complete 4 steps without aid with supervision
(1) able to complete < 2 steps, needs minimal assist
(0) needs assistance to keep from falling/ unable to try   _____

13. Standing unsupported, one foot in front

Instruction: (Demonstrate) Place one foot directly in front of the other. If you feel that you can't place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot.

(4) able to place foot tandem independently and hold 30 seconds

(3) able to place foot ahead of other independently and hold 30 seconds

(2) able to take small step independently and hold 30 seconds

(1) needs help to step but can hold 15 seconds

(0) loses balance while stepping or standing   _____

14. Standing on one leg

Instruction: Stand on one leg as long as you can without holding on to an external support.

(4) able to lift leg independently and hold >10 seconds

(3) able to lift leg independently and hold 5-10 seconds

(2) able to lift leg independently and hold up to 3 seconds

(1) tries to lift leg, unable to hold 3 seconds, but remains standing independently

(0) unable to try or needs assist to prevent fall   _____

TOTAL SCORE   _____/56

APPENDIX G

ACTIVITIES-SPECIFIC BALANCE CONFIDENCE SCALE (ABC)

Name: _____   Date: _____

Level of Confidence
(0-100%)

1. Walking around the house   _____

2. Walking up and down stairs   _____

3. Picking up slipper/something from the floor   _____

4. Reaching at your eye level   _____

5. Reaching while on your tiptoes   _____

6. Reaching while standing on a chair   _____

7. Sweeping the floor   _____

8. Walking outside to a nearby car   _____

9. Getting in/out of a car/transport   _____

10. Walking across a parking lot   _____

11. Walking up and down a ramp   _____

12. Walking in a crowded mall   _____

13. Being bumped while walking in a crowd   _____

14. Using an escalator while holding the railing   _____

15. Using an escalator without holding the railing   _____

16. Walking on slippery floors   _____

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