AN ABSTRACT OF THE DISSERTAITON OF

D. Clark Dickin for the degree of Doctor of Philosophy in Human Performance presented on February 15, 2002.
Title: Sensory Integration during Balance in Individuals with Differing Degrees of Senile Dementia of the Alzheimer's Type.

Abstract approved: Signature redacted for privacy.
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Individuals with Senile Dementia of the Alzheimer Type (SDAT) are up to four times more likely to sustain an accidental fall than their non-demented peers. The cause(s) of this elevated risk, however, has not been determined. Prior to the design of balance retraining programs, researchers need to uncover the nature of the elevated risk in these individuals. To address this need, the present investigation compared postural stability in altered sensory environments both between individuals with mild-SDAT and moderate-SDAT, and to a group of apparently healthy older adults (HOA) (N = 6, 6, & 10, respectively), using the Sensory Organization Test® (SOT). Measures of percent equilibrium (%EQ) and movement velocity (MV) were used to assess postural stability for the six sensory conditions. It was hypothesized, based on neural impairment patterns associated with SDAT, that postural stability would decrease as a function of disease severity when sensory information was

inaccurate or absent. The results of this study, however, failed to support this hypothesis, in that the moderate-SDAT group performed more like the HOA than the mild-SDAT group. Significant differences in %EQ ($p < .008$) were found between the mild-SDAT group and both the HOA and moderate-SDAT groups in the absence of vision and when the vestibular system was the primary source of accurate positional information. Significant differences were also evident between the HOA group and the mild-SDAT group when the environment was unaltered and when vision was inaccurate. No significant differences were evident for the measure of MV; however, moderate to large effect sizes were obtained for both %EQ and MV for a number of the sensory conditions between the three groups. These results suggest that individuals become less visually dependent in the later stages of the illness, possibly due to the increased frequency of visual disturbances associated with disease progression. To compensate for these disturbances individuals may shift from being visually dependent to relying more on somatosensory and vestibular inputs for the control of upright balance. Future longitudinal research is needed to determine if the shift away from vision as the preferred sensory system is causally related to disease progression.

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Sensory Integration during Balance in Individuals with Differing Degrees of Senile Dementia of the Alzheimer's Type

by

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A DISSERTATION

submitted to

Oregon State University

In partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Presented February 15, 2002
Commencement June 2002

ACKNOWLEDGMENTS

I am eternally grateful to many people for their assistance and encouragement during the preparation of this dissertation. Integral in this process was my mentor Dr. Debra Rose, who allowed me the opportunity to grow as a scholar and as a researcher. Her support and encouragement throughout the many stages of the dissertation process were invaluable. Special thanks are also given to Dr. Karen Hooker, Dr. Vicki Ebbeck, Dr. Jeff McCubbin, and Dr. Warren Suzuki for their participation on my doctoral committee.

To my family, I extend the deepest appreciation for encouraging me to pursue my dreams and providing the support that allowed me to achieve them. Finally, I want to extend my deepest gratitude to my wife, Holly Dickin, without whom, I would never have completed this dissertation. Her love and encouragement enabled me to continue when my motivation was low and allows me to continue to grow as a person. Without her unconditional support I could not possibly have gotten this far.

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Sensory Integration during Balance in Individuals with Differing Degrees of Senile Dementia of the Alzheimer's Type

INTRODUCTION

An unintentional loss of balance, resulting in a fall, can cause both physical and psychological trauma, often leading to a self-imposed activity restriction even in the absence of disability or injury (Tinetti, Richman & Powell, 1990). This decreased level of activity over time will result in decreased functional ability, strength, and overall endurance. Even without experiencing a fall, older adults are at a greater risk for falling with advancing age due to physiological changes associated with the aging process (e.g., decreased sensitivity in sensory receptors, decreased reaction time, decreased muscular strength). Approximately one third of all individuals aged 65 years and older sustain a fall each year, with the percentage of sustained falls resulting in injury increasing exponentially with age (Sattin et al., 1990). Moreover, in individuals aged 75 years and older, the long-term effects of falls are the leading cause of death, more than all other unintentional injuries combined (Baker & Harvey, 1985; Morris, Rubin, Morris & Mandel, 1987). Falling is also the leading cause of hospital admission in the United States, regardless of age (Baker & Harvey, 1985).

In the case of individuals with Senile Dementia of the Alzheimer's Type (SDAT), the occurrence of falls and the incidence of resultant hip fracture is more than three times greater than for individuals without the illness (Buchner & Larson, 1987; Morris et al., 1987; Melton, Beard, Kokmen, Atkinson & O'Fallon, 1994). Once an individual with SDAT has sustained a fall, his/her time until institutionalization is shorter than for an individual without the dementing illness (Morris et al., 1987). If the individual is forced to move into a long-term care facility as a result of a fall, or progression of the disease, the annual cost for caring for the patient increases considerably (Leon, Cheng & Neumann, 1998). As such, there is an urgent need to reduce the frequency of falling and delay the premature institutionalization of these individuals. This urgency is further necessitated by the knowledge that falls incidence rates are at their highest level during the first week of admission into a long-term care facility (13.2 falls per person year vs. 4.1 in the two year period following institutionalization) (van Dijk, Oda, Meulenberg, van de Sande & Habbema, 1993). In order to better understand why the risk for falls is elevated in this population over that of their age-matched peers, investigations first need to identify the possible underlying cause(s) and then institute environmental modifications and/or intervention programs designed to reduce the frequency of falls associated with this dementing illness.

Although the cause of the increased falls-risk in community dwelling SDAT patients has not been identified, it is unlikely that any single factor will completely explain the increased falls incidence in these individuals. However, a number of potential risk factors have been identified that may partially explain the elevated risk observed in these individuals. These factors include the presence of SDAT, impaired balance and gait, increased incidence of wandering, increased oculomotor reaction time, poor vision, arthritis, toxic reactions to drugs, muscle weakness, and peripheral neuropathy (Buchner & Larson, 1987; Morris et al., 1987; Nakamura, Meguro & Sasaki, 1996; Pirozzolo and Hansch, 1981). Although it is accepted that the presence of SDAT itself is a risk factor for falling, the research is equivocal with regard to the effect disease severity has on balance and gait (O'Keeffe et al., 1996; Morris, et al., 1987; van Dijk et al., 1993). Possible explanations for the ambiguous findings may stem from the less precise measurements used to evaluate gait and balance in the past, or the experimental design used to test function. If changes in balance and gait are occurring with increases in disease severity, measurements capable of detecting subtle and complex changes may help to better discriminate between individuals with different levels of dementia.

In the case of individuals with SDAT, the integration of sensory information used to maintain balance may be compromised due to changes in brain structure and function caused by the illness. Information from visual, auditory, and somatic inputs, from the temporal, occipital, and parietal lobes are integrated in the parahippocampal gyri, which is one of the initial areas of the brain affected by the disease (Van Hoesen, 1982). The parahippocampal gyri not only experience a proliferation of plaques and tangles in SDAT patients, these regions also have a reduced capacity for the production of dendritic connections known to occur in age-matched apparently healthy individuals (Flood & Coleman, 1990). The decreased function of the parahippocampal gyri in individuals with SDAT may partially explain the increased falls-risk in this population, due to a decreased ability to integrate sensory information needed to maintain balance.

The parietal lobes of the brain are an additional area in which the integration of sensory information occurs (Stein, 1985); these regions of the brain are also severely affected during the early stages of the dementing illness.

The parietal lobes of the brain are involved in the integration of visual, auditory, and proprioceptive information with efferent motor signals (Stein, 1985). Any reduced ability to adequately and correctly integrate sensory information with motor signals would decrease the CNS's ability to successfully guide goal-directed movements. Since the parahippocampal gyri and the parietal lobes are two of the earliest regions of the brain affected by the dementing illness (Smith, 1998), the ability to integrate sensory information may be affected early in the disease progression, becoming increasingly more affected as the disease progresses.

The ability to more accurately detect changes in motor function with SDAT may assist in the preliminary diagnosis of the disease. Although most measures of motor function have been found to be insensitive to the severity or presence of SDAT (MacLennan, Ballinger, McHarg & Ogston, 1987), advances in technology in the last decade may prove to be invaluable in the detection of subtle system-based changes in motor function. One area of research that has detected small differences between SDAT patients and age-matched control participants is relative to the control of balance.

Although the number of studies that have investigated balance abilities in individuals with SDAT is limited, recent investigations incorporating computerized posturography have proved useful in the diagnosis and discrimination of the stages of disease progression. In an early study conducted by Visser (1983) using computerized posturography, an increase in total path sway during eyes open upright stance was observed when individual's with SDAT were contrasted to age-matched control participants. Although this measure of balance poses a relatively low postural challenge to the participant, significant differences were evident between SDAT patients and age-matched control participants. This measure however, was unable to discriminate between the different stages of dementia of the Alzheimer's type. In a more recent investigation, Alexander et al. (1995) measured the ability of SDAT and apparently healthy participants to maintain balance while standing on a narrow beam attached to a force platform, under both stationary and moving surface (i.e., translation of the force plate) conditions with their eyes closed. The results indicated that the participants who were unable to maintain upright stance during the moving surface conditions were more cognitively impaired than those individuals able to maintain upright stance during the anterior and posterior translations of the surface. The ability to discriminate between disease severity in the later study may have been due not only to the increased difficulty of the balance task presented, but also to the moving (i.e., translation) support surface and/or the decreased sensory information available to the participants (i.e., standing on a surface that is more narrow than the base of support with absent vision). One limitation, however, with each of the previous investigations was the absence of conditions, within each study, measuring changes in balance with different levels of sensory information made available to the participant. Although visual information was eliminated and somatosensory inputs reduced (narrow beam) in the experiment conducted by Alexander et al, the type and amount of sensory information available to the individual was not systematically manipulated.

When an individual assumes a position of upright stance on a firm support surface, the three sources of sensory information available are the vestibular, somatosensory, and visual systems (Nashner, 1989). In order to maintain a position of upright balance individuals must maintain the Center of Gravity (COG) within the boundaries of their base of support. If the COG exceeds the limits of the base of support, a modification of the existing base must be made (i.e., stepping) or the individual must grasp a supporting structure (i.e., handrail) to prevent the impending fall. Considerable overlap exists in the afferent information derived from each of the three available sources of sensory information. For example, when an individual leans forward on a firm surface with eyes open a stretch occurs in the triceps surae muscle group (somatosensory input), visual flow moves toward the individual, and the linear and angular acceleration of the head is perceived by the vestibular system. This redundancy of information between the three sensory systems enables the individual to maintain balance across a variety of different sensory environments by comparing and contrasting the different afferent sensory signals and determining which system or systems are providing valid positional information. While it is desirable to have all three sensory systems functioning properly, an individual can often maintain upright balance despite the complete or partial loss of one of the sensory systems (i.e., blindness, peripheral neuropathy). In order to determine how well an individual is able to organize and integrate the three sensory systems used to maintain balance, he/she can be placed in situations that systematically distort or remove one or more of the sources of sensory information, thereby allowing for assessments of the remaining systems. With the use of the Sensory Organization Test® (SOT) (NeuroCom International Inc.) it is possible to systematically manipulate which sensory system(s) are available for maintaining upright balance. In some cases, the system(s) may be eliminated and/or rendered inaccurate as a source of positional information. In addition, sensory conflict can be introduced by creating a mismatch between the sensory systems. It is in these situations that the ability to prioritize sensory information, from the multiple sources, is needed in order to resolve the sensory conflict and enable the individual to determine which system(s) is providing the correct postural information (Nashner, 1989). By systematically manipulating the sensory information available to an individual, objective assessments can be made with regard to his/her sensory organization abilities.

In order to evaluate the ability of individuals with SDAT to integrate the available sensory information during upright stance, both eyes-open and eyes-closed conditions need to be presented to the same group of patients. Although Alexander et al. (1995) required participants to perform the beam standing conditions with their eyes-closed, no comparisons were made to postural control for eyes-open conditions. Of particular importance to the present investigation are the differences revealed between the mild and moderate levels of dementia severity reported by Alexander et al. (1995). Alexander and colleagues reported that the difficulty experienced, while attempting to maintain balance on a narrow beam, by individuals with SDAT increased as a function of disease severity. One problem however, reported by the researchers was the high levels of anxiety and resulting unwillingness to stand on the beam without vision. This problem resulted in an overall decrease in the number of participants who completed all testing conditions.

In an attempt to reduce the anxiety experienced by the participants, and to limit the amount of lost data due to participant attrition, a surface larger than the participants' base of support, but capable of being sway-referenced (i.e., the support surface responds to the movement of the individual in the anterior-posterior direction by platform rotation in the direction of postural sway) could be substituted for the narrow beam. Although the task is inherently different (beam standing reduces the amount of somatosensory information, while sway-referencing renders somatosensory information inaccurate), sway-referencing allows the participant to assume a position with the entire length of their feet supported, while rendering the somatosensory information inaccurate.

The ability to integrate sensory information in individuals with DAT was studied by Chong, Horak, Frank, and Kaye (1999) by having individuals stand on a force plate capable of being sway-referenced to the individuals' anterior/posterior sway. In addition to the sway-referenced platform, the patients were surrounded on three sides (anterior, left, and right surround) and from above, which could also be sway-referenced. Sway-referencing the visual surround enabled the researchers to render the available visual information inaccurate in the same way the somatosensory system was rendered inaccurate. Systematic manipulations of the amount of sensory feedback available to the participants, by sway-referencing the support surface and/or visual surround, enabled the researchers to measure sensory integration abilities in these individuals. The results of their investigation indicated that individuals with DAT experienced difficulties in suppressing incongruent sensory information when trying to maintain balance. The researchers suggest that individuals with the dementing illness have an impaired ability to use vestibular information when somatosensory and visual information was no longer available or was inaccurate. Moreover, some patients were unable to adapt their postural control despite repeated exposure to the altered environmental conditions. Although differences were found between the DAT patients and the apparently healthy control participants, the researchers reported that no significant differences existed in performance as a function of disease severity. However, the number of DAT participants representing the various stages of the illness was small. In addition to the limited sample size used in their investigation, Chong et al. (1999) combined two different sub-types of the disease, early- and late-onset Alzheimer's disease, into one dementia group. This is particularly problematic given that the two stages of disease onset are characterized by different degrees of neurological dysfunction and different progression rates of cognitive decline, and consequently represent different sub-groups of the dementing illness (Lendon, Ashall & Goate, 1997; Fujimori et al., 1998). Differences between the two disease subgroups include the speed with which the disease progresses, the degree of parietal dysfunction, and the severity of the cognitive and physical symptoms associated with the disease (Fujimori et al., 1998). In all cases, more dysfunction is associated with the less common early-onset Alzheimer's disease. As a result of the different disease etiologies, experiments that assess sensory integration abilities associated with only one subtype of the dementing illness may uncover more definitive functional differences as a function of disease severity.

SIGNIFICANCE

This study assessed postural stability in individuals with mild and moderate levels of SDAT and apparently healthy age-matched participants, in altered sensory environments. Specifically, the six condition Sensory Organization Test® (SOT) was used to assess postural stability between individuals with mild and moderate levels of SDAT and apparently healthy older adults. The SOT systematically manipulates the somatosensory and visual systems individually and concurrently to assess function in these systems as well as in the vestibular system. By manipulating the somatosensory and visual systems, the integrity of the unaltered vestibular system is assessed in both the absence of sensory information from the other two systems, and when sensory conflict is introduced between the three systems. Research has demonstrated that as individuals age, postural stability decreases in both normal and altered sensory environments (Woollacott et al., 1986). Moreover, when an individual with SDAT is placed in an altered sensory environment his/her ability to maintain balance has been found to be impaired to a greater degree than in apparently healthy older adults (Chong et al., 1999). As a result of the impaired balance control in individuals with SDAT researchers have reported high falls incidence rates and consequently a high rate of hip fracture in this population (Buchner & Larson, 1987; van Dijk et al., 1993). Some investigations report the increased falls-risk to be at least three times greater in this population when compared to apparently healthy older adults (Buchner & Larson, 1987; van Dijk et al., 1993). The cause(s) of the increased falls-risk, however, has not been identified.

As such the primary purpose of this investigation was twofold: (a) to assess the sensory contributions to postural stability in altered sensory environments in individuals with mild and moderate levels of SDAT, and (b) to determine the degree to which postural stability is affected by disease severity. A secondary purpose of this investigation was to identify sensory deficits affecting postural control that may benefit from the development and implementation of a balance retraining intervention. Researchers have demonstrated that the presence of SDAT does not preclude an individual with the illness from learning and retaining motor skills (Dick et al., 1996). With a better understanding of the cause(s) for the increased falls-risk in this population, coupled with the preservation of the ability to learn motor skills, interventions may be designed to decrease the incidence of falling in individuals with SDAT. The development of targeted intervention programs may also help to delay the premature institutionalization of SDAT patients by allowing them to retain their independence further into the course of the dementing illness.

RATIONALE

Integration of the senses used to maintain balance is essential in order for individuals to orient themselves to, and enable them to interact with, the environment. Although no single sensory system measures the actual location of the body's COG directly, the redundancy and overlap between the three sensory systems can be integrated and used to maintain balance in most situations. As a result of this overlap in sensory information, individuals with dysfunction in one sensory system may be able to utilize information from the remaining systems to remain upright (Nashner, 1989). Several situations, however, require the utilization of sensory information from multiple sources simultaneously (e.g., standing on a compliant surface, visual flow while standing still, etc.). In situations like these, the individual may be required to assess the accuracy of each sensory system and utilize those systems that are providing the most accurate positional information. If the information transmitted from one or more of the senses is inaccurate or conflicting, the individual will need to quickly ascertain which system is providing the most accurate information and select it as the primary source for maintaining balance.

Two brain regions responsible for the integration of sensory information are the parietal lobes (Stein, 1985) and the parahippocampal gyri (Van Hoesen, 1982). Dementia of the Alzheimer's type has been shown to produce dramatic changes in brain function, particularly in these regions. Although motor function is relatively spared by the dementing illness (Dick et al., 1996), the organization and integration of sensory information used to guide goal-directed movements may not be appropriately interpreted in these individuals. This compromised ability may, in turn, negatively affect movement responses in altered or changing sensory environments. The cause of sensory integration changes in these individuals may be due to the insidious structural changes associated with SDAT in the hippocampus and the parietal lobes (Minoshima, Frey, Koeppe, Foster & Kuhl, 1995; Van Hoesen, 1982). It was therefore, the purpose of this investigation to compare the ability of individuals with mild and moderate levels of SDAT severity, with a third group of age-matched apparently healthy older adults, in their ability to appropriately select and utilize sensory information used for maintaining upright stance in altered sensory environments.

METHODS

Eighteen older adults who met the National Institute of Neurological and Communicative Disorders and Stroke and Alzheimer's Disease Association (NINCDS-ADRDA) criteria for probable late-onset senile dementia of the Alzheimer's type, (7 mild SDAT, and 11 moderate SDAT) were recruited for this study, with the majority of participants residing in the community (1 mild and 4 moderate participants were recruited from residential care facilities). Limiting this investigation to mild and moderate levels of SDAT was done to provide a starting point for assessing the effects of disease severity on postural stability. Further, the number of verbal commands associated with this type of balance testing is likely to be more difficult for individuals with severe levels of SDAT to comprehend and respond to appropriately. An additional 12 apparently healthy older-adult participants were recruited from the local community. To assess the current level of disease severity each individual was assessed using the Mini-Mental State Exam (MMSE) (Folstein, Folstein & McHugh, 1975), and the Dementia Severity Rating Scale (DSRS) (Clark & Ewbank, 1996). The DSRS was used to obtain information from the caregiver about the current level of function of the individual with SDAT across a number of domains (e.g., cognitive function, personal care, memory, and mobility).

To assist in the completion of paperwork and to corroborate the accuracy of the individual with SDAT answers, each participant was asked to bring an individual actively involved in his/her life (collateral source) to all testing sessions. Prior to the cognitive and physical assessments, a medical history questionnaire (Appendix A) was administered at the participant's place of residence, or at another location of their choice (e.g., senior center or community center). The questionnaire was used to determine if the participants had been diagnosed with any of the following medical diagnoses known to affect postural stability: (1) cerebrovascular accident, (2) Parkinson's disease, (3) multiple sclerosis, or (4) dementia other than Alzheimer's type. Individuals with any of these medical diagnoses were excluded from further participation in this study.

Each participant completed two 1 to 1 ½ hour testing sessions. The initial assessment was performed by a licensed physical therapist to determine the existence of peripheral impairments within the three sensory systems that could account for postural instability in altered sensory environments. In order to control for the effects of impairment in the sensory systems, several tests of peripheral function of the sensory systems important to balance were performed (see Appendix B for descriptions of each test):

1. Somatosensory: Proprioception and Vibration Sense
2. Vestibular: Hallpike Maneuver or Sidelying test, Halmagi head thrust
3. Visual-Vestibular integration: Extra Ocular Eye Movements (smooth pursuits, saccades, and VOR cancellation)
4. Vision: Visual Acuity, and Depth Perception

Following the completion of the initial day of assessments (informed consent, medical history questionnaire, and peripheral sensory testing) 12 individuals with SDAT and ten apparently healthy older adults remained eligible for the second day of testing using the Sensory Organization Test® (SOT). The second day of assessments required each individual to perform the SOT twice with the initial set of trials serving as practice trials to familiarize each participant with the testing protocol. Between the first and second performance of the SOT each participant was given a 20 minute rest period. The second performance of the SOT was used for subsequent analyses to assess sensory integration and dynamic postural control. Exposing each participant to the testing procedures at least once prior to data collection was necessary in order to decrease the anxiety of the participants, increase the participant's familiarity with the testing protocol, and to increase the reliability of the testing procedure (Ford-Smith, Wyman, Elswick, Fernandez & Newton, 1995). All individuals who were determined to be eligible for participation on the second assessment day were able to attempt all three trials on each of the six conditions of the SOT.

EQUIPMENT

All balance testing was conducted on the SMART Balance Master® (SMART-BM; NeuroCom International Inc., 9570 SE Lawnfield Rd. Clackamus OR, 97015), which consists of two 9" x 18" force platforms connected in the middle by a pin joint. Each force plate is supported by two force transducers designed to measure vertical forces along the Z axis, with a fifth transducer located in the middle of the two plates designed to measure shear forces along the Y axis. The combined 18" x 18" force platform as well as a three-sided visual surround room was capable of being sway-referenced to the individual's Anterior-Posterior (A-P) postural sway. Sway referencing enables the visual surround, the support surface, or both to rotate simultaneously in response to the participant's A-P sway. The SOT was used to evaluate the sensory integration ability of all participants. The SOT consists of six conditions that create a situation of inaccurate or absent sensory feedback, resulting in situations of sensory conflict. Each participant completed three trials in each of the six conditions of the SOT as follows:

1. Eyes open, firm support surface,
    - Information from all three sensory systems is available to the participant
2. Eyes closed, firm support surface,
    - Visual information is not available to the participant
3. Eyes open, sway-referenced visual surround, firm support surface,
    - Visual information is made inaccurate with the moving visual surround
4. Eyes open, sway-referenced support surface
    - Somatosensory information is made incongruent to body sway
5. Eyes closed, sway-referenced support surface
    - Visual information is not available, somatosensory information in made incongruent to body sway
6. Eyes open, sway-referenced visual surround, sway-referenced support surface.
    - Both visual and somatosensory information are incongruent to body sway

PROCEDURES

Sensory organization test

Each participant was fitted with an upper-body harness to ensure safety during performance of the SOT. The harness was attached to an overhead support system affixed to the SMART-BM®. Although the harness system did not limit movement of the participant during the testing, it did provide support in the event that balance was compromised during any portion of the test. In addition to the harness, a tester was in close proximity at all times to ensure participant safety. Once on the platform, the participant's feet were placed in a standardized position according to the manufacture's specification.

Once the feet were positioned the participants attempted each of the 18 trials (three trials in each of the six sensory conditions) of the SOT. A trial was marked as unsuccessful if the individual changed his/her base of support (e.g., stepped off the force plate, or lost balance) during any of the 18 trials. Any trial in which the individual was not able to complete the entire 20 second trial was recorded as a fall. In the event that an individual sustained a loss of balance the trial was stopped and the participant was re-positioned on the platform for the remaining trials. Following the completion of conditions 3 and 5, each participant was provided with a two minute seated rest period. Additional two minute rest periods were provided to individuals that either requested additional rest or if the experimenter deemed it necessary due to fatigue of the participant.

Measures of interest

Mean movement velocity (MV)

Calculations were performed to obtain the mean MV for each trial. Individual trials within each condition were then averaged to decrease the effects of intertrial variability on the SOT (Ford-Smith et al., 1995). Prior to MV calculations, all raw data from the four load cells recording vertical forces were passed through a 3 Hz fourth-order zero-phase-shift Butterworth filter. The filtered data were then used to calculate MV of the individual's center of gravity in the A-P direction using the following formulas (NeuroCom International, Inc, 1999):

I) Left and right force platform center of vertical force (Py):

$$Py = \{[(LF+RF) - (LR+RR)] \div (LF+RF+LR+RR)\} \times 4.20 \text{ inches}$$

where LF, RF, LR, RR represent the data from the left front, right front, left rear, and right rear load cells, respectively, and 4.20 inches is the distance from the X axis to the load cell in the y direction.

II) Calculation of COG sway angle from forceplate information:

$$\theta = \text{arcsine}\,(4.2 \div H_{cog}) - 2.30^{\circ}$$

where H_{cog} is the distance from the ground to the individuals center of gravity (.5527 x total height), and 2.30° indicates the forward lean from vertical of the center of gravity during upright stance.

III) COG velocity:

$$V_{COG} = \frac{\theta i_{+1} - \theta i_{-1}}{2\Delta t}$$

IV) Mean COG velocity:

$$\text{Mean}_{COG} = \frac{\sum_{i=50}^{j=1950} V_{COG}(i_{thru}j)}{1900}$$

<u>Percent mean equilibrium (%EQ)</u>

For all conditions of the SOT, a percent mean equilibrium score (%EQ) was obtained, from the SMART-BM Version 7.0.4 software, based on the degree of postural sway exhibited during each individual trial. The equilibrium score is based on a normal sway range of 12.5 degrees in the A-P direction (NeuroCom

International, Inc, 1999). The mean score was calculated using the following formula:

$$\%EQ = [(12.5° - (\theta max - \theta min)/12.5°))*100]$$

where 12.5° is the maximal active COG sway range in the anterior-posterior direction. Postural sway was measured at 100 Hz. %EQ scores for each trial were used to assess differences between the age-matched apparently healthy older adults and the older adults with either mild or moderate levels of senile dementia of the Alzheimer's type recruited for this investigation.

Losses of balance

The number of losses of balance experienced on each of the six test conditions was also recorded to determine if differences in the frequency of falling across the six conditions existed between apparently healthy older adults and the two groups of older adults with SDAT. A loss of balance (LOB) was operationally defined as any instance in which an individual altered the position of his/her base of support, fell into the supporting harness, or was unable to keep his/her eyes closed for the entire 20-second trial.

The measurement of losses of balance was assessed not only to examine differences in fall frequency between the three experimental groups, but also to assess the adaptation abilities of individuals with varying degrees of SDAT severity. Previous research has suggested that individuals with SDAT have an impaired ability to adapt to sensory conditions that require the predominant use of vestibular information to maintain balance (Chong et al., 1999). To further address the adaptation abilities of individuals with SDAT, and to increase the reliability of the SOT, the current investigation included practice trials for each condition of the SOT (Ford-Smith et al., 1995). Measurements of center of gravity movement velocity were included to determine if the frequency of postural sway differed as a function of the illness or its severity in the altered sensory environments. The third measure, %EQ, was included (1) as a standard measure calculated by the SMART BM version 7.0.4 software, allowing for comparisons to be made to other individuals with SDAT without the need for extraneous calculations, and (2) because %EQ scores are provided for both successful and unsuccessful trials, thereby maintaining data from all trials.

STATISTICAL ANALYSES

To assess the effect of dementia on SOT performance, MV data for each of the six conditions tested were analyzed using separate univariate analyses of variance (ANOVAs). To correct for the multiple comparisons, the original alpha level ($p \leq .05$) was adjusted to $p \leq .008$. Trials in which a participant sustained a loss of balance were analyzed separately from successful trials to eliminate potential differences in postural sway between falling and non-falling trials. Each condition was assessed independently to retain sample sizes for conditions in which no participants sustained a loss of balance (conditions 1 – 4). If a significant group main effect was obtained a follow-up Student-Neuman-Keuls (SNK) test was performed.

To assess the effect of dementia on %EQ, a 3 x 6 (group x condition) ANOVA with repeated measures for the factor of condition was used. %EQ for each of the six conditions of the SOT was compared between the three groups (apparently healthy older adults, mild SDAT, moderate SDAT). In the event that significant main effects were obtained, follow-up univariate ANOVAs, polynomial contrasts and SNK tests were performed to determine the nature of the main effects. To address differences in adaptation abilities between the three groups, qualitative assessments of each condition of the SOT were made with regard to the number of LOB(s) sustained across the three trials within each condition. Finally, effect sizes were calculated, using group means and pooled standard deviations, for the dependent measures of MV and %EQ for each pairwise comparison between the three groups and for each of the six conditions of the SOT.

RESULTS

PARTICIPANTS

Eighteen individuals with senile dementia of the Alzheimer's type (SDAT) volunteered to participate in this study. Following the initial cognitive and sensory assessment, however, six participants were no longer eligible to participate in the study. One participant was unable to continue due to an adverse reaction to medication for a sinus infection, two were excluded due to impaired sensory function (one with somatosensory and proprioceptive loss possibly due to edema in the lower extremities, and one with abnormal Hallpike and sidelying results), one was lost due to a history of a cerebrovascular accident, and two were excluded due to severe levels of dementia. The data were subsequently analyzed for twelve SDAT participants, of which six were classified as mild SDAT and six as moderate SDAT. An age-matched group of twelve apparently healthy older adults were also assessed; however, one participant was subsequently excluded due to a history of repeated falls in the previous year, and a second individual was excluded due to impaired sensory function, resulting in a control group comprised of 10 apparently healthy older adults. The demographics for each group are presented in Table 1. Univariate ANOVAs for each of the five demographic variables assessed in this investigation (i.e., age, education level, number of medications, fall history, and level of physical activity) only revealed significant group differences for activity level ($F(2,19) = 8.08$, $p < .01$). Post hoc Student-Newman-Keuls (SNK) comparisons revealed significant differences in activity level between the apparently healthy older adults and each of the SDAT groups. The main effect of activity level, however, violated the assumptions of homogeneity of regression slopes when compared with the dependent variable of MV on condition five of the Sensory Organization Test (SOT). Consequently activity level was not used as a covariate for any of the analyses (Tabachnick & Fidell, 1996).

Table 1: Demographic results for apparently healthy older adults, mild SDAT and moderate SDAT groups. (* $p < .01$)

Group	N	Age (YEARS)	Education (YEARS)	Number of Medications	Falls (# IN LAST YEAR)	Activity per Week *
Apparently healthy Older Adults	10	76.50 ± 3.81	15.2 ± 2.20	2.40 ± 1.84	0.10 ± 0.32	5.50 ± 1.43
Mild SDAT	6	82.00 ± 3.58	14.5 ± 5.05	3.50 ± 1.52	0.33 ± 0.52	1.83 ± 2.99
Moderate SDAT	6	79.33 ± 5.54	13.00 ± 1.67	3.00 ± 1.79	1.50 ± 1.76	1.17 ± 2.86

CENTER OF GRAVITY MEAN MOVEMENT VELOCITY (MV)

Table 2 and Figure 1 illustrate summary data for the center of gravity MV results for the three groups in each of the six conditions of the SOT. The individual ANOVAs performed on each sensory condition did not reveal significant group differences ($p > .008$). However, conditions one, four, and five approached significance ($p < .05$) suggesting that group differences may have existed but statistical significance did not exceed the adjusted alpha level ($p \leq .008$), potentially as a result of a small sample size. Measurements of effect size were subsequently calculated for each condition of the SOT using group means and pooled standard deviations (Cohen, 1962). Large effect sizes (> .80) were obtained between the mild SDAT group and the apparently healthy older-adult group for the firm surface/stable visual surround condition (condition one), the firm surface/no vision condition (condition two), the moving surface/stable visual surround condition (condition four), and for the moving surface/no vision condition (condition five). A large effect size (> .80) was also obtained between the moderate SDAT group and the apparently healthy older-adult group for the moving surface/stable visual surround condition (condition four). Pairwise effect size comparisons were also performed between the mild and moderate SDAT groups. A number of large effect sizes (> .80) were found including the firm surface/stable visual surround condition (condition one), the firm surface/moving visual surround condition (condition three), the moving surface/no vision condition (condition five), and the moving surface/moving visual surround condition (condition six). In all cases, however, the moderate SDAT group demonstrated smaller mean movement velocities than the mild SDAT group, indicating a higher level of stability in each of these four sensory conditions. It is also interesting to note that for conditions three (firm surface/moving visual surround) and six (moving surface/moving visual surround) there was a moderate negative effect size (≥ -0.45) between the moderate SDAT group and the apparently healthy older-adult group, indicating that the moderate SDAT group also exhibited smaller mean movement velocities than their apparently healthy older-adult peers in each of those sensory conditions. Table 3 summarizes each of the pairwise effect size comparisons across the six conditions of the SOT.

Table 2: Movement velocity and % equilibrium mean values for each condition of the SOT for apparently healthy older adults, mild SDAT and moderate SDAT groups.

	MOVEMENT VELOCITY (deg/s)			PERCENT EQUILIBRIUM (% stability)		
	Apparently healthy Older Adults	Mild SDAT	Moderate SDAT	Apparently healthy Older Adults	Mild SDAT	Moderate SDAT
Condition 1	.36 ± .07	.51 ± .13	.39 ± .12	94.90 ± .82	92.39 ± .68	93.56 ± 1.96
Condition 2	.65 ± .19	.96 ± .39	.73 ± .23	91.80 ± 2.72	85.67 ± 3.56	90.50 ± 2.75
Condition 3	.57 ± .19	.67 ± .14	.49 ± .13	92.00 ± 2.42	89.61 ± 2.73	92.50 ± 1.72
Condition 4	1.10 ± .37	1.75 ± .52	1.50 ± .47	82.50 ± 4.65	66.84 ± 16.78	74.56 ± 10.86
Condition 5	2.57 ± .78	3.80 ± .85	2.61 ± .59	55.80 ± 14.31	18.78 ± 18.30	43.00 ± 15.81
Condition 6	2.44 ± 1.07	2.81 ± .67	2.09 ± .34	55.50 ± 11.13	44.11 ± 23.49	41.39 ± 33.20

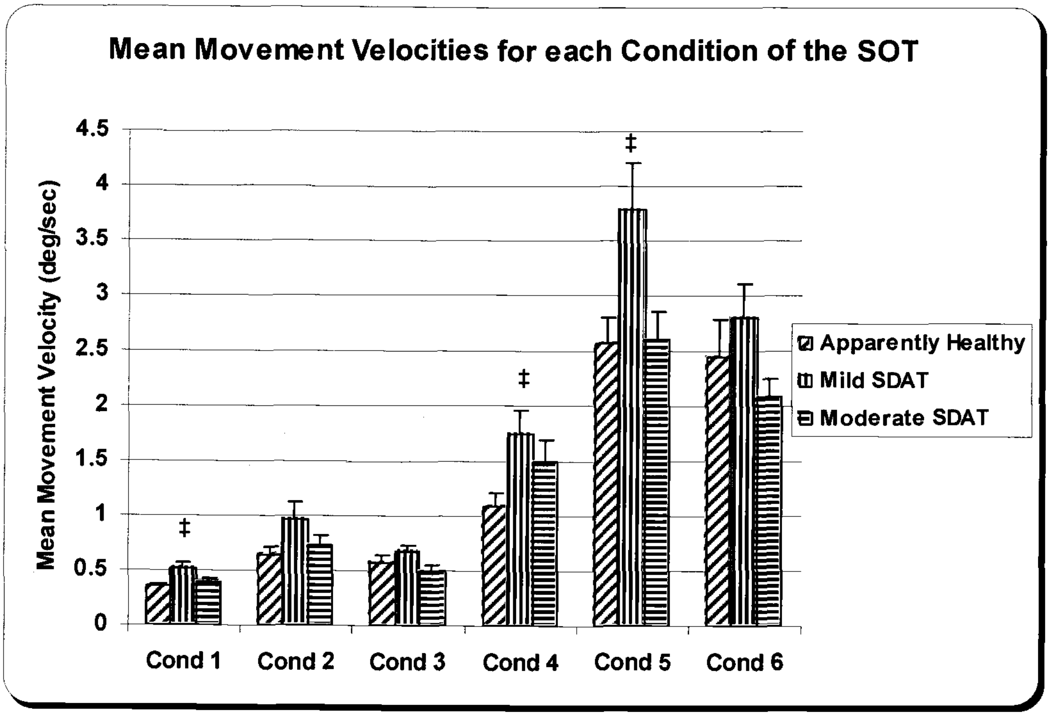

Figure 1: Estimated marginal means for average movement velocity at each of the six conditions of the SOT for the apparently healthy and SDAT groups.
[‡ approaching significance at $p \leq .05$ between mild SDAT & apparently healthy older-adult groups]

PERCENT MEAN EQUILIBRIUM (%EQ)

The %EQ data for the three groups at each of the six conditions of the SOT are illustrated in Table 2 and Figure 2. To correct for sphericity violations, within-subject degrees of freedom were adjusted using Huynh-Feldt epsilons (Harris, 1985). The resulting 3 x 6 (group x condition) ANOVA with repeated measures for the factor of condition, revealed a significant main effect for condition ($F_{(5, 95)} = 99.58$, $p < .001$, $eta^2 = .840$, power = 1.00) and a significant main effect for group ($F_{(2, 19)} = 6.42$, $p = .007$, $eta^2 = .403$, power = .849); however, the higher order interaction between group and condition was also significant ($F_{(10, 95)} = 3.04$, $p = .014$, $eta^2 = .242$, power = .860). Follow-up univariate ANOVAs were then performed for each of the six conditions of the SOT to determine the nature of the interaction effect. The results of the multiple comparisons, using an adjusted alpha level of $p \leq .008$, revealed significant differences for the firm surface/stable visual surround condition (condition 1), the firm surface/no vision condition (condition 2), and the moving surface/no vision condition (condition 5). Follow-up polynomial contrasts revealed a significant quadratic trend for all three significant conditions, indicating a non-linear relationship between the apparently healthy older-adult group and the two SDAT groups. Figure 2 illustrates this quadratic (non-linear) effect for the significant conditions (1, 2, & 5) with lower %EQ scores recorded for the mild SDAT group when compared to either the apparently healthy older-adult or the moderate SDAT groups. Similar, but non-significant quadratic trends were also evident for sensory conditions three and four. Additional follow-up comparisons, to determine the effect of dementia severity on each condition of the SOT, were conducted using SNK post hoc comparisons. Significant differences were evident between the mild SDAT group and the apparently healthy older-adult group on conditions one, two, four, and five, and between the moderate and mild SDAT groups on conditions two and five.

To assess the practical significance of the results for %EQ, effect sizes were calculated for each of the eighteen possible pairwise comparisons. As was the case for the dependent variable of MV, large effect sizes were recorded for a number of the comparisons. Large effect sizes (> .80) were evident between the mild SDAT group and the apparently healthy older-adult group for conditions one through five. Large effect sizes were also evident between the moderate SDAT group and the apparently healthy older-adult group for conditions one, four, and five, indicating that the apparently healthy older-adult group exhibited lower frequency postural sway than both the mild and moderate SDAT groups. For condition three, however, there was a small negative effect size (-.24) between the apparently healthy older adult and moderate SDAT groups. Surprisingly, the moderate SDAT group produced a smaller frequency of postural sway when compared to the apparently healthy older adult group, indicating an increased postural stability for the moderate SDAT group. The mild and moderate SDAT groups also differed in terms of their %EQ scores with large effect sizes evident for conditions one through three and for condition five, with the moderate SDAT showing higher levels of postural stability. Between-group effect sizes for %EQ are presented in Table 3.

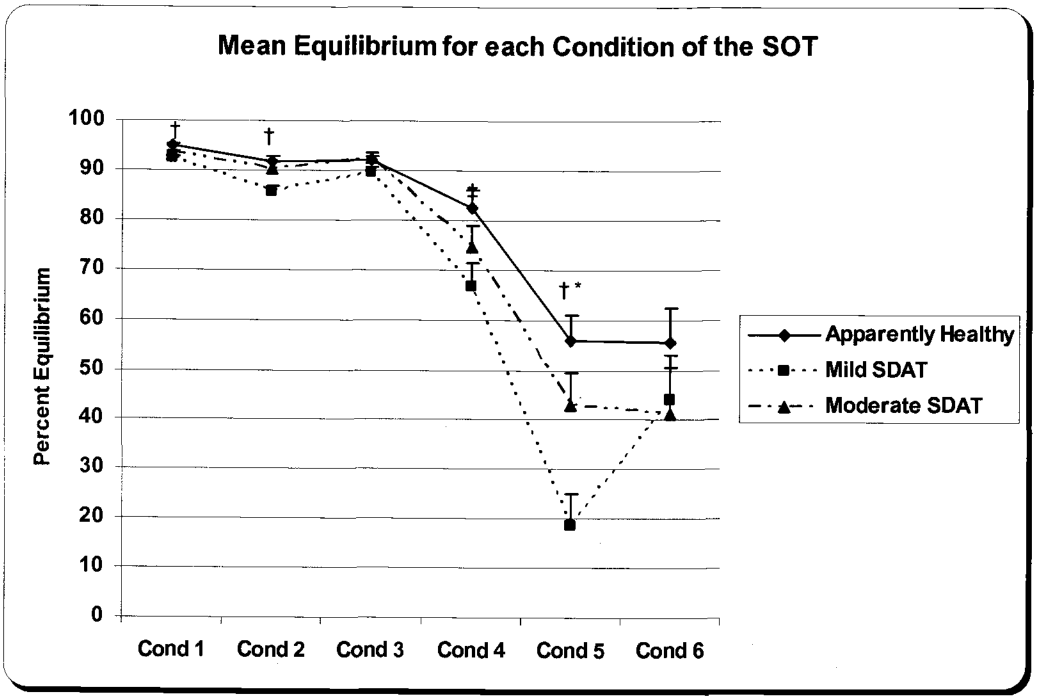

Figure 2: Percent equilibrium means at each of the six conditions of the SOT for the apparently healthy and SDAT groups.
[† mild SDAT group different from apparently healthy older-adult group at $p \leq .008$; ‡ mild SDAT group different from apparently healthy older-adult group at $p \leq .05$; * mild SDAT group different from moderate SDAT group at $p \leq .05$]

Table 3: Effect sizes for each condition of the SOT for Movement Velocity and Percent Equilibrium for each pairwise comparison between the apparently healthy older-adult group and the two SDAT groups. (‡Large effect sizes > 0.8)

	MOVEMENT VELOCITY			PERCENT EQUILIBRIUM		
	Apparently healthy vs. Mild SDAT	Apparently healthy vs. Moderate SDAT	Mild SDAT vs. Moderate SDAT	Apparently healthy vs. Mild SDAT	Apparently healthy vs. Moderate SDAT	Mild SDAT vs. Moderate SDAT
Condition 1	1.42 ‡	.29	.98 ‡	3.34 ‡	.90 ‡	.79
Condition 2	1.03 ‡	.42	.71	1.94 ‡	.48	1.52 ‡
Condition 3	.61	-.50	1.36 ‡	.93 ‡	-.24	1.27 ‡
Condition 4	1.43 ‡	.95 ‡	.50	1.29 ‡	.95 ‡	.55
Condition 5	1.51 ‡	.07	1.62 ‡	2.25 ‡	.85 ‡	1.42 ‡
Condition 6	.41	-.45	1.36 ‡	.62	.57	.09

LOSSES OF BALANCE

No losses of balance were recorded for any of the three groups (apparently healthy, mild, moderate SDAT) across the first four sensory conditions of the SOT. Consequently, only conditions five and six were contrasted for group differences. The frequency of balance losses for each group across the three trials in conditions five and six are illustrated in Figure 3. The first trial of the moving surface/no vision condition (condition five) resulted in a large number of individuals sustaining a loss of balance (9 of the 22 participants). For this initial trial in condition five, five of the mild SDAT group and two each from the moderate SDAT group and apparently healthy older adult group lost their balance. For the remaining two trials in condition five, half of the individuals in the mild SDAT group were unable to maintain balance while the moderate SDAT group only sustained one and two losses of balance for trials two and three, respectively. The large number of falls in this condition is not surprising since it has been shown that as many as half of all apparently healthy older adults sustain a loss of balance on the initial trial of this condition (Wolfson et al., 1992). Although individuals in the apparently healthy older adult group were able to adopt the appropriate strategies to maintain balance with repeated testing on condition five, half of the individuals in the mild SDAT group and as many as one third of those in the moderate SDAT group continued to experience difficulty throughout the three trials on this condition. For condition six, in which both the support surface and the visual surround were sway-referenced to the individual's A-P sway, there were only slight differences between the two SDAT groups; however, both SDAT groups sustained considerably more losses of balance than the apparently healthy older adult group. Across all trials of conditions five and six of the SOT there were four losses of balance sustained by the apparently healthy older adult group, as compared to 15 and 11 losses of balance for the mild and moderate SDAT groups, respectively (see Figure 3).

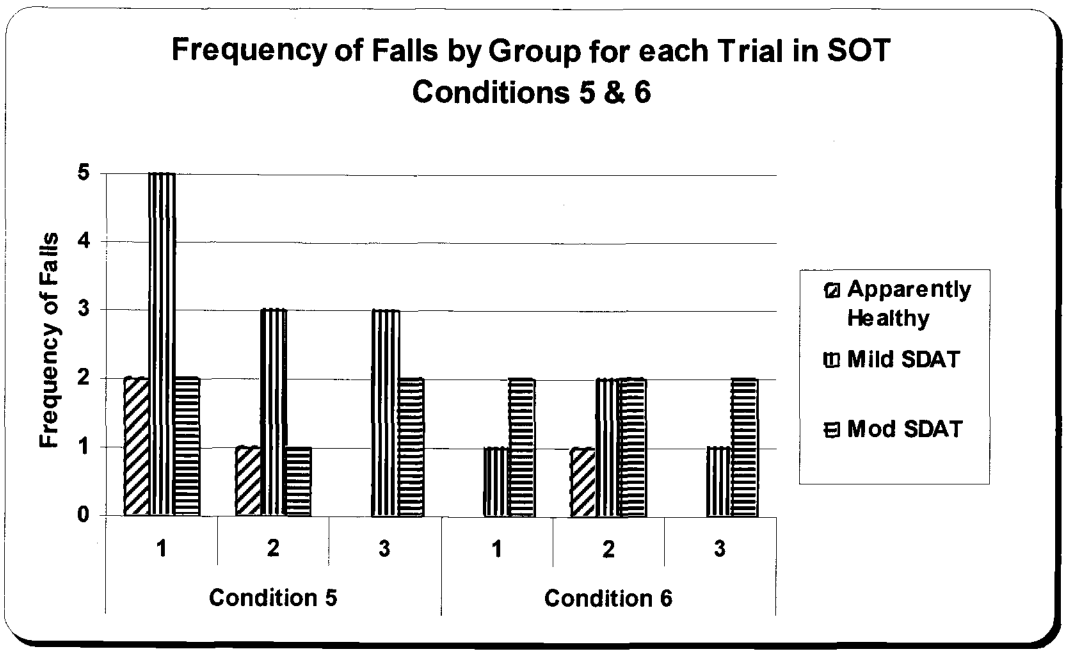

Figure 3: Frequency of falls by trial for conditions 5 and 6 of the SOT as a function of group.
[For condition five, two mild SDAT were unable to maintain balance for any of the three trials. For condition six, one mild SDAT and 2 moderate SDAT were unable to maintain balance for any of the three trials]

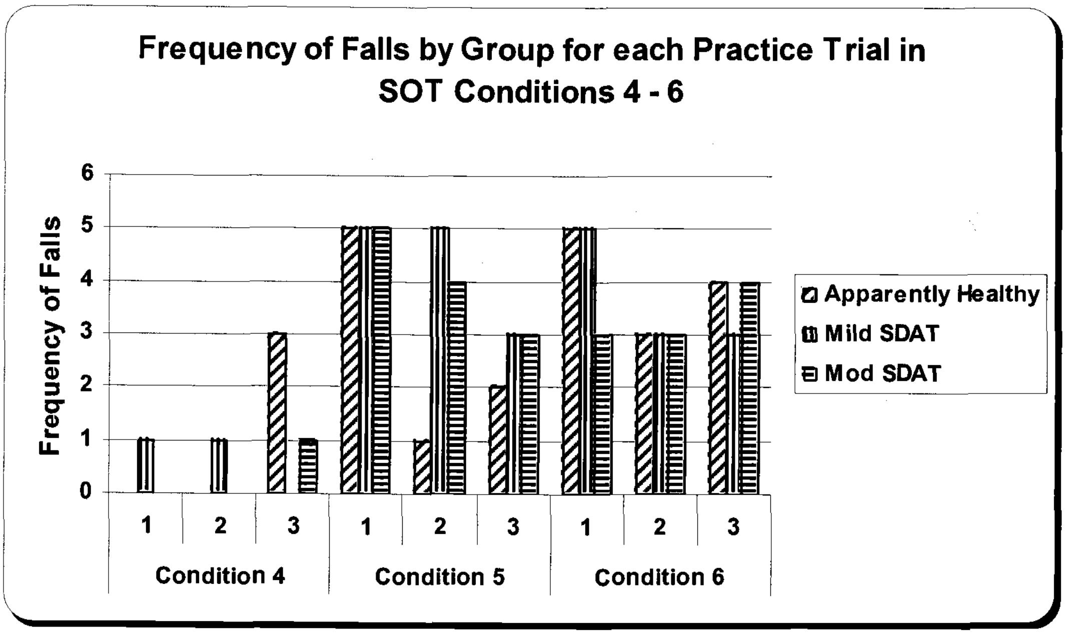

Figure 4: Frequency of falls as a function of group for practice trials in conditions 4, 5 and 6 of the SOT.

DISCUSSION

Standing balance in individuals with SDAT was impaired in altered sensory environments when compared to their apparently healthy peers. The findings of the present study are consistent with the findings of previous investigations with respect to the fact that the presence of the illness adversely affects postural stability, and that the progressive decline associated with the illness did not result in increased levels of instability (Morris et al., 1987; Buchner and Larson, 1987). In contrast to previous studies, the results of this investigation indicated that individuals with moderate levels of SDAT actually performed more like the apparently healthy older-adult group than the mild SDAT group. Postural stability, as measured by %EQ, was found to differ significantly between the mild SDAT group and both the moderate SDAT and apparently healthy older-adult groups in both sensory conditions in which visual information was unavailable (conditions 2 & 5). Significant differences were also found for %EQ between the mild SDAT group and the apparently healthy older-adult group when all sensory systems were available (i.e., condition 1), and when the somatosensory inputs were inaccurate (i.e., condition 4 of the SOT). In addition to the significant group x condition differences in %EQ in this study several large effect sizes were found for both %EQ and MV. These findings indicate that potential group differences exist on several of the six conditions of the SOT and warrant further investigation (table 3).

Sensory conditions 2 and 5, in which individuals were instructed to close their eyes, required a dependency upon somatosensory inputs to the greatest degree and vestibular information, to a lesser degree in order for balance to be successfully maintained. Chong et al. (1999) previously reported that when individuals with DAT were instructed to close their eyes while standing on a firm surface, postural sway decreased due to the reduced sensory processing load produced by eliminating visual information. Although the current investigation did not find evidence for a reduction in postural sway when the eyes open and eyes closed firm surface conditions were directly compared, apparently healthy individuals and those with moderate levels of SDAT were significantly more stable than the mild SDAT group when visual information was removed (condition 2) (see figure 2). These differences in postural stability between the present investigation and the study by Chong and colleagues may stem from the latter study's inclusion of both early- and late-onset dementia. By combining the two disease subtypes it is difficult to determine if the higher levels of postural stability in the eyes closed firm surface condition is a result of the two disease subtypes, the younger age of the individuals assessed, or some other unexplained factor.

The group differences observed in postural stability in the firm surface, no-vision condition (condition 2) suggests that the mild SDAT group was more dependent on visual information for maintaining balance, and experienced a greater degree of instability than the moderate SDAT group, when vision was removed. This visual dependency was also evidenced using the manufacturer's visual preference calculation. Preferences scores of 100.6, 130.0, and 100.5 were obtained for the apparently healthy, mild SDAT, and moderate SDAT groups, respectively. The visual preference score is used to assess a participant's preference for visual information regardless of its appropriateness. Higher scores indicate a greater dependence upon the visual system [preference score = (condition 3 + condition 6)/(condition 2 + condition 5)].

This difference in stability between the two dementia groups is possibly the result of the moderate SDAT group benefiting from the reduced sensory processing load experienced during the eyes closed conditions as suggested by Chong et al. (1999). This transition away from visual dependency between mild and moderate SDAT can be explained within the context of the developmental model of selective optimization with compensation, proposed by Baltes and colleagues (Baltes, Dittmann-Kohli & Dixon, 1984; Baltes, 1987; Baltes, 1997). The compensation demonstrated by the moderate SDAT group, as evidenced by a reduction in visual dependency, may be an effort to make up for the disturbances in visual function associated with the illness by shifting the reliance from the visual system to the remaining sensory systems. Since visual disturbances increase as a function of disease severity (Cronin-Golomb et al., 1991; Mendez, Tomsak & Remler, 1990), the decreased visual dependency may represent an attempt to compensate for the visual disturbances occurring more frequently in the moderate SDAT group when compared to the mild SDAT group. Individuals participating in this investigation were screened for occulomotor function assuring that participants were able to sense and track objects in the environment. Each individual's primary caregiver was also questioned regarding the occurrence of uncorrected visual problems, of which no reports of visual impairments were found. We did not, however, assess each individual's sensitivity to movement which may have contributed to the explanation of the findings in this investigation.

This trend of decreased postural stability in the absence of visual information was also evidenced between individuals with mild and moderate SDAT in the more challenging sensory condition in which somatosensory input was also rendered inaccurate by sway-referencing the support surface (condition 5). This condition required individuals to obtain positional information, almost entirely, from the vestibular system by eliminating input from the somatosensory and visual systems (Hobeika, 1999).

This finding of decreased postural stability in the mild SDAT group may also be attributed to the decreased visual dependency evident in those individuals with moderate levels of SDAT. As the frequency and magnitude of visual disturbances increase, with concomitant increases in dementia severity, balance impairments are more likely to occur. It is not until the individuals' balance-related strategies become insufficient to maintain balance, however, that a shift away from visual dependency occurs (Hobeika, 1999). Due to the cross-sectional nature of this investigation it is impossible to determine if disease progression caused the shift in visual dependency, or if the moderate SDAT group was less visually dependent prior to the onset of the illness. To address this issue further, future research needs to adopt a longitudinal approach and assess individuals with the illness throughout the progression of the illness.

For conditions in which vision was available (conditions 1 & 3) it was also determined that the moderate SDAT group performed better than the mild SDAT group. Although the results were not significant for these conditions, moderate to large effect sizes were found for both %EQ and MV, indicating a potential group difference and an area warranting further research. For condition 3 in which vision was sway-referenced (i.e., available but no longer useful for maintaining balance) the individual needs to rely upon sensory information from the somatosensory system, and to a lesser degree the vestibular system to maintain balance. If an individual is visually dependent postural stability will decrease to a greater degree than for individuals who are not as dependent upon vision for balance. In the case of individuals with mild SDAT the sway-referencing of the visual surround resulted in greater instability than the moderate SDAT group, again suggesting a greater dependence on visual information in individuals with mild SDAT. This visual dependency is further illustrated in condition one, in which the sensory environment is not altered, thereby allowing the individual to utilize sensory information from all three systems. If individuals with mild SDAT are dependent upon a visual system experiencing disturbances, postural stability is likely to be lower than for individuals with a functioning visual system (i.e., the apparently healthy group), or individuals less dependent upon a compromised system (i.e., the moderate SDAT group).

Maintaining balance in environments that require vestibular function (e.g., conditions 5 & 6 of the SOT) was previously suggested to cause extreme difficulties for individuals with SDAT (Chong et al., 1999). Chong and colleagues reported that in spite of a functioning vestibular system, individuals with SDAT were unable to maintain balance in sensory environments in which only the vestibular system was providing accurate positional information. The fact that the majority of individuals with the dementing illness in the present investigation, both mild and moderate in severity, were able to maintain balance in sensory environments requiring the use of vestibular information contradicts previous findings. Similar to the Chong et al. study, individuals in the current investigation were determined to have functioning vestibular systems; however, unlike the Chong et al. study, several participants with SDAT in this investigation were able to maintain balance in similar altered sensory environments. Two primary differences between the present investigation and the Chong et al. study may account for the contradictory findings obtained.

First, Chong and colleagues did not differentiate between early- and late-onset DAT. The deleterious effects of early-onset dementia are known to progress in a more rapid manner resulting in more profound impairment than that of late-onset DAT. As such, the inclusion of individuals with early-onset DAT may explain, at least in part, the inability of the DAT group in the Chong et al. study to maintain balance in conditions requiring vestibular information. Secondly, the present investigation utilized practice trials prior to assessing postural stability. Given that the incorporation of practice trials was found to be necessary when testing a apparently healthy older-adult population, in order for reliable results to be obtained using dynamic posturography (Ford-Smith et al., 1995), it was considered essential for this investigation that a similar protocol be adopted for all groups tested. Of course we do not know if additional practice beyond what is required when testing apparently healthy older adults should have been provided for the two groups with SDAT. What was evident in this investigation was a trend for improved performance with repeated testing even in the more demanding conditions in which the individual is required to utilize vestibular information almost entirely (condition 5), or in conditions of sensory conflict in which only the vestibular system is providing accurate positional information (condition 6). This trend was seen by the improved performance (i.e., decreased frequency of falls) between practice trials and the final performance of the SOT (Figure 4 and Figure 3, respectively). It is unknown, however, if the individuals with the dementing illness would have benefited from further practice trials. Establishing the reliability of the SOT when administered to individuals with SDAT is also an area of future research.

In addition to the differences observed between the two dementia groups, the apparently healthy older-adult group was more stable in all sensory conditions when compared to the mild SDAT group, and in all but two conditions (conditions 3 & 6 for MV and condition 3 for %EQ) when compared to the moderate SDAT group. Although the differences between the moderate SDAT group and the apparently healthy older-adult group were not significant, large effect sizes were recorded for three of the six conditions (conditions 1, 4, & 5) for %EQ, and one of the six conditions (condition 4) for the measure of MV. These effect size comparisons indicate that although only a few significant findings were evidenced, postural stability in both groups with the dementing illness was impaired to some degree, regardless of dementia severity, thereby supporting previous investigations in this population. Even though this investigation demonstrated significant differences and large effect sizes between the apparently healthy older adult group and both groups of individuals with

SDAT, future investigations should further delineate and equate groups based on the frequency and type of physical activity performed. Specifically, differentiation should be made between activities involving sensory manipulations (i.e., compliant surfaces, reduced or absent vision) and those performed in a constant sensory environment (i.e., treadmill walking, aerobic dance, circuit training). This delineation may help to further differentiate between apparently healthy individuals and individuals with SDAT in terms of postural stability.

Since a large number of individuals with SDAT are residing in the community, and therefore are required to divide attention between balance and the performance of a secondary task (i.e., walking and reading signs, talking, avoiding obstacles), researchers need to assess postural stability during the performance of secondary tasks. Additionally, since individuals, at least in the early stages of the illness, are highly dependent on visual information, postural stability needs to be tested during the performance of secondary visual tasks (i.e., responding to visual stimuli, identifying pictures/shapes). Researchers have shown that even in an apparently healthy older-adult population (Shumway-Cook & Woollacott, 2000) the performance of a secondary task during the execution of the SOT resulted in impaired balance. This impaired ability to perform a secondary task during SOT performance is likely to cause even greater impairments in individuals with SDAT due to the known difficulties performing dual-tasks in this population (Nebes & Brady, 1989; Nestor, Parasuraman, Haxby & Grady, 1991).

Although individuals with severe levels of SDAT were excluded from this study, postural stability was assessed in one individual with moderate to severe SDAT (MMSE score = 0; DSRS score = 34). It was discovered that not only could this individual maintain balance in environments requiring the use of vestibular information as the primary source of positional information (condition 5 & 6), the individual was also able to adapt to the condition that caused the greatest difficulty during practice (condition 5). Although these results are based on only one individual with moderate to severe dementia, they demonstrate a preserved ability to adapt to altered sensory environments well into the progression of the illness, and also demonstrates that motor adaptation can occur for more complex real-world tasks than has been shown in the past using simple motor skills (Dick et al., 1996; Hirono et al., 1997). In order to determine if these balance related skills can be retained, future investigations need to assess the retention of balance abilities in individuals with the illness over an extended period of time.

These findings of a preserved ability to adapt to altered sensory environments in individuals with SDAT could prove to be extremely important to both the individual with the disease and their family. If researchers and/or therapists are able to identify the cause(s) of an individual's balance problem, and provided the cause is modifiable, interventions can be developed that could lead to the individual with the illness being able to retain functional independence further into the progression of the illness. This loss of functional independence is often lost following an injurious fall and/or as a function of aging. By maintaining the independence of individuals with SDAT for an extended period of time, research has demonstrated that the quality of life of both the person and the caregiver can be enhanced by delaying admission into a long-term care facility (Forsyth & Ritzline, 1998).

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APPENDICES

APPENDIX A

Medical History Questionnaire

Ruby Gerontology Center — Health/Activity Information
Lifespan Wellness Clinic

Name____

Address ____________________________ City ___________State ______ Zip ________

Home Phone # ________________ Gender: Male ___ Female ___

Age: _____ Year of birth: _______ Height: ________ Weight: _________

Ethnicity _____________ Highest level of education completed ______________

Whom to contact in a case of emergency ______________________

Ph# _______________

Name of your physician ___________________ Phone # __________________

2. Have you ever been diagnosed as having any of the following conditions?

	Yes (√)	Year of onset (Approximate)
Heart attack	___	___________
Transient ischemic attack	___	___________
Angina (chest pain)	___	___________
High blood pressure	___	___________
Stroke	___	___________
Peripheral vascular disease	___	___________
Diabetes	___	___________
Neuropathies (problems with sensations)	___	___________
Respiratory disease	___	___________
Parkinson's disease	___	___________
Multiple sclerosis	___	___________
Polio/Post polio syndrome	___	___________
Epilepsy/seizures	___	___________
Other neurological conditions	___	___________
Osteoporosis	___	___________

	Yes (√)	Year of onset
Rheumatoid arthritis	___	___________
Other arthritic conditions	___	___________
Visual/depth perception problems	___	___________
Inner ear problems /Recurrent ear infections	___	___________
Cerebellar problems (ataxia)	___	___________
Other movement disorders	___	___________
Chemical dependency (alcohol and/or drugs)	___	___________
Depression	___	___________

2. Have you ever been diagnosed as having any of the following conditions?

	Yes (√)	**Year of onset (Approximate)**
Cancer	___	___________

If YES, describe what kind

____

Joint replacement	___	___________

If YES, which joint (e.g. knee, hip) and side (left or right)

____

Cognitive disorder	___	___________

If YES describe condition

____

Uncorrected visual problems	___	___________

If YES, describe type

____

Any other type of health problem?	___	___________

If YES, describe condition

____

3. Do you currently suffer any of the following symptoms in your legs or feet?

	Yes (√)
Numbness	___
Tingling	___
Arthritis	___
Swelling	___

4. Do you currently have any medical conditions for which you see a physician regularly?

YES or NO

If YES, please describe the condition(s)

____

____

5. Do you require eyeglasses? YES or NO

6. Do you require hearing aids? YES or NO

7. Do you use an assistive device for walking?

No___ Yes ___ Sometimes ___ Type?____________

8. List all medications that you currently take (including 'over-the-counter' medications)

Type of medication	**For what condition**
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

9. Have you required emergency medical care or hospitalization in the last **three years?**

YES or NO

If YES, please list when this occurred and briefly explain why.

____

____

____

10. Have you ever had any condition or suffered any injury that has affected you balance or ability to walk without assistance? YES or NO

If YES, please list when this occurred and briefly explain condition or injury

____

____

____

11. How many times have you fallen **within the past** year? ______

Did you require medical treatment? YES or NO

If YES to either question, please list the approximate date of the fall, the medical treatment required and the reason you fell <u>in each case</u> (e.g., uneven surface, going down stairs, etc.).

____

____

____

____

____

12. Are you <u>worried</u> about falling? (check)

1 - - - - - - - 2 - - - - - - - 3 - - - - - - - - 4 - - - - - - - - 5 - - - - - - - 6 - - - - - - - 7

not a little moderately very extremely

13. How would you describe your health?

____ Excellent ____ Very good ____ Good ____ Fair ____ Poor

14. In the past 4 weeks, to what extent did health problems limit your everyday physical activities (such as walking and household chores)?

Not at all ___ Slightly ___ Moderately ___ Quite a bit ___ Extremely ___

15. How much "bodily pain" have you generally had during the past 4 weeks? (While doing <u>normal activities of daily living</u>):

None ____ Very little ____ Moderate _____ Quite a bit_____ Severe____

16. In general, how much depression have you experienced within the past 4 weeks?

Not at all ____ Slightly ___ Moderately ___ Quite a bit ___ Extremely ____

17. In general, how would you rate the quality of your life? (Circle the appropriate number)

1 - - - - - - - 2 - - - - - - - 3- - - - - - - - 4 - - - - - - - 5 - - - - - - - 6- - - - - - - 7
very low low moderate high very high

18. **Please indicate you ability to do each of the following (*circle appropriate response).***

		Can Do	Can Do With Difficulty	Cannot Do
a.	Take care of own personal needs--like dressing yourself	2	1	0
b.	Bathe yourself, using tub or shower	2	1	0
c.	Climb up and down a flight of stairs (like to a second story in a house)	2	1	0
d.	Walk outside one or two blocks	2	1	0
e.	Do light household activities -- like cooking, dusting, washing dishes, sweeping a walkway	2	1	0
f.	Do own shopping for groceries or clothes	2	1	0
g.	Walk 1/2 mile (6-7 blocks)	2	1	0
h.	Walk 1 mile (12-14 blocks)	2	1	0
i.	Lift and carry 10 pounds (full bag of groceries)	2	1	0
j.	Lift and carry 25 pounds (medium to large suitcase)	2	1	0
k.	Do most heavy household chores -- like scrubbing floors vacuuming, raking leaves	2	1	0
l.	Do <u>strenuous</u> activities -- like hiking, digging in garden, moving heavy objects, bicycling, aerobic dance exercises, strenuous calisthenics, etc.	2	1	0

19. In general, do you currently require household or nursing assistance to carry out daily activities?

No ___ Yes ___ If yes, please check the reasons(s)?

a. Health problems ___
b. Chronic pain ___
c. Lack of strength or endurance ___
d. Lack of flexibility or balance ___
e. Other reasons: ____

20. In a typical week, how often do you leave your house? (to run errands, go to work, go to meetings, classes, church, social functions, etc.)

_____ less than once/week _____ 3-4 times/week
_____ 1-2 times/week _____ most every day

21. Do you currently participate in regular physical exercise (such as walking, sports, exercise classes, house work or yard work) that is strenuous enough to cause a noticeable increase in breathing, heart rate, or perspiration?

Yes ____ No ____ If yes, how many days per week?

One ___ Two ___ Three ___ Four ___ Five ___ Six ___ Seven ___

22. When you go for walks (if you do), which of the following best describes your walking pace:

____ Strolling (easy pace, takes 30 min. or more to walk a mile)
____ Average or normal (can walk a mile in 20-30 minutes)
____ Fairly brisk (fast pace, can walk a mile in 15-20 minutes)
____ Do not go for walks on a regular basis

23. Did you require assistance in completing this form?

None (or very little) _____ Needed quite a bit of help ______

Reason: ________________________

Thank You!

APPENDIX B

Tests of Peripheral Sensory Function

SOMATOSENSORY TESTING

Proprioception

To test proprioception, the participant was placed in a seated position on a plinth, with knees flexed to approximately 90 degrees. The participant was barefoot and was unable to see their feet hanging over the edge of the plinth. In this position, the participant was asked to respond verbally to passive movements (two to five degrees up or down from neutral) of the great toe and ankle joints of both lower extremities. Each of the four joints was assessed twice, with the great toes tested first. If the participant was able to correctly perceive the direction of passive movement of the great toes, the ankle joints were not tested since decreased sensation in the extremities moves from distal joints to joints that are more proximal. If the participant failed to correctly perceive movement in the toes the ankles of both extremities were then assessed.

An ordinal scale (zero to four) was used for this test. A score of four was an indication of normal directional perception in all four joints, while a score of two indicated normal perception in only two of the four joints. A score of two could occur if the individual had normal perception in both ankles, or in the ankle and toe of one extremity. Individuals were given a score of zero if impaired proprioception was exhibited in all four lower extremity joints. A score of less than two indicated impaired proprioception in three or more of the four lower extremity joints and resulted in the individual being excluded from further participation.

Vibration sense

The ability to perceive vibration of the head of the first metatarsal and the medial malleolus of both lower extremities was assessed. To accomplish this, participants were positioned in the same seated position used to perform the proprioceptive test. Participants were then asked to respond verbally immediately upon application and removal of a tuning fork. Two trials were performed on each of the four bony prominences of the lower extremities. The metatarsals were tested prior to the malleoli of each lower extremity. If the individual correctly perceived the onset and termination of vibration of the first metatarsal bilaterally, the malleoli were not assessed.

An ordinal scale (zero to four) was again used for this test. A score of four indicated normal vibration sense of all four bony prominences, while a score of two indicated normal perception in only two of the four locations. A score of two could occur if the individual had normal perception in both malleoli or in the malleolus and metatarsal of one extremity. Individual were given a score of zero if impaired vibration sense was exhibited in all four lower extremity prominences. Individual with scores of less than two were excluded from further participation, indicating impaired vibration sense in three or more of the four lower extremity prominences.

VESTIBULAR TESTING

Hallpike maneuver

The Hallpike maneuver was used to assess peripheral vestibular function. This assessment required the participant to sit with legs extended and head turned at a 45 degree angle to one side. From the sitting position, the individual was moved quickly, by the physical therapist, to a supine position with the head supported and extended over the end of the table about 30 degrees below horizontal (Herdman, 1999). The maneuver was performed with the head turned once to the left and once to the right side. Participants were observed for nystagmus, and were questioned for the presence of vertigo after being moved into the Hallpike position. The presence of vertigo and nystagmus indicate benign paroxysmal positional vertigo (BPV) in the participant (Herdman, 1999). Individuals who experienced vertigo and nystagmus during execution of the Hallpike maneuver were excluded from further participation.

Sidelying test for benign positional vertigo

An alternative test for assessing BPV was performed for participants who exhibited insufficient cervical range of motion or high anxiety. This test required the participant to sit at the edge of the examination table while the therapist turned his/her head 45 degrees to the right or left. While keeping the head in the turned position, the participant was moved into a side-lying position onto the side being tested. The participant remained in the lying position for 60 seconds before returning to an upright position. The test was then repeated to the other side. Individuals who experienced vertigo and/or nystagmus lasting for < 60 seconds were excluded from further participation.

Halmagyi head thrust maneuver

Participants were in the seated position and instructed to focus on a target 5 – 10 feet in front of the participant's eyes. The therapist explained the test to the individual and then demonstrated head position, speed, and extent of the head movements that were to be performed during the test. The therapist then stood in front of the participant and tilted the participants head 30 degrees (chin tuck). The participant's head was held firmly and then gently turned from side to side at a slow speed. The therapist watched for any loss of tracking smoothness and/or corrective saccades. The head was then quickly thrust (a very small distance) right or left and the participant was instructed to remain focused on the distant target. Abnormal function was indicated if the participant was unable to keep his/her eyes focused on the target during each head thrust, and resulted in the individuals being excluded from further participation.

After head shake test

For this assessment the participant was seated at the end of an examination table. The therapist tilted the individuals' head down 30 degrees, and asked the participant to close his/her eyes. The participants head was quickly "shaken" from side to side 20 times and stopped quickly without the head changing its position. The therapist observed the stability of the eyes and watched for the presence of nystagmus. More than 3 – 4 beats of the eyes once the head is stopped is indicative of peripheral impairment and resulted in the individuals being excluded from further participation.

Extraocular eye movements

Smooth pursuit eye movements were evaluated with the head fixed and eyes tracking an object moving below 1-2 Hz. Saccadic interruptions during tracking and or cogwheeling motions of the eyes indicated abnormal function. Saccadic eye movements were tested with the head fixed. The participant was instructed to rapidly move the eyes between two targets. Observations of eye movement velocity, accuracy, and conjugate eye motion were used to determine normality of function. Finally, vestibular-ocular reflex cancellation was assessed by instructing the participant to move the head and a held object in phase. Abnormal function was indicated by in phase motion of head and eyes that could not be maintained throughout the test.

VISUAL TESTING

Visual acuity

A Snellen eye chart was used to assess visual acuity. Participants were required to stand at a distance of 20 feet from the eye chart, close one eye, and say aloud the lowest line on the chart they can read. The test was then repeated on the remaining eye to assess visual acuity bilaterally. Participants were excluded if visual acuity was poorer than 20/100 (with corrective lenses, if normally used).

Depth perception

Depth perception is the binocular ability to perceive distances. The Frisby Stereotest Screener, a 6 mm diameter plate consisting of four square visual images encompassing a stereo-acuity range of 600 to 85 of arc, was used to assess depth perception. One of the four images on the plate is a "circle-in-depth", a circle that appears either recessed or raised depending on which side of the plate is being viewed.

The plate was placed on a piece of white paper in front of the participant. At which time the individual was asked to point to or name which of the four circles was in an offset position. Responses were recorded as correct or incorrect. Following the completion of each trial, the participant was asked to close his/her eyes while the disk was randomly rotated to a new position, upon which time the next trial was completed. Each participant was asked to perform ten trials, and the number correct was recorded. Due to cognitive impairment in individuals with SDAT, and the complexity of the instructions needed for this test, the four individuals (two individuals with mild and two with moderate SDAT) that were not able to understand the task were not excluded from further participation based on their acceptable visual acuity scores.

APPENDIX C

Review of Literature

INTRODUCTION

Dementia of the Alzheimer's type (DAT) is characterized by a subtle onset with a progressive decline in intellectual function that results in changes in behavior, personality, impaired judgment, and decreased ability to interact with the environment (Morris, 1996; Daly, 1999; Hamdy, 1998). Diagnosis of this disease, however, has proven difficult and in fact, the only conclusive way to diagnose an individual with DAT is through brain biopsy or postmortem autopsy (Braak et al., 1999; Growdon, 1999; Huppert & Tym, 1986; McKhann et al., 1984). Because of the uncertain diagnosis of DAT, several researchers have attempted to identify or develop methods that would increase the accuracy of determining the presence of the illness. A diagnosis of DAT is complicated due to its similarities to other dementing illnesses such as lewy body dementia, vascular dementia, and frontotemporal dementia (Almkvist & Winblad, 1999; Kalaria & Ballard, 1999). Although a definitive diagnosis is not attainable without histopathological analysis, current diagnostic criteria are capable of correctly diagnosing (antemortem diagnosis) the presence of Alzheimer's disease with a success rate of 80 – 95% (Growdon, 1999; Morris, 1996; Gearing et al., 1995).

AGE AT ONSET OF ALZHEIMER'S DISEASE

When an individual is diagnosed with DAT, four possible disease categorizations can be made based on the age at which the individual experiences the onset of the dementing illness and the presence of a genetic predisposition to the illness. Familial cases of DAT, both early and late onset, account for approximately 5 – 10% of all cases (Forsyth & Ritzline, 1998). The remaining 90% of all individuals with DAT are classified as non-familial with no distinguishable onset, with only a small percentage of those having an age of onset prior to the age of 65 years (Forsyth & Ritzline, 1998). Differentiating between early- and late-onset DAT is important for researchers and clinicians because it can assist in determining the rate of progression of the illness, and may help to determine the efficacy of intervention strategies. In all cases, early-onset DAT progresses at a faster rate than the more common late-onset senile dementia of the Alzheimer's type (SDAT) (Mungas, Reed, Ellis, & Jagust, 2001; Hamdy, 1998; Harvey, 1998; Morris, 1995). A number of specific factors that have been shown to differentiate between the two disease subtypes include substantially greater reductions in regional cerebral blood flow (Jagust, Reed, Seab & Budinger, 1990), and substantially greater reductions in cerebrospinal fluid volumes in early onset DAT when compared to SDAT cases (Sullivan et al., 1993). Differences in the patterns of metabolic activity are also evident from positron emission tomography, with the predominant abnormalities occurring in the frontal and temporoparietal cortex in the early-onset DAT as compared to a more global involvement in late onset cases (Mielke, Herholtz, Grond, Kessler & Heiss, 1991).

ALZHEIMER'S DISEASE DIAGNOSIS: CLINICAL

In an attempt to standardize the clinical procedures used to identify and diagnosis individuals' with DAT, a number of diagnostic criteria have been developed. The three most commonly used criteria are those provided by the American Psychiatric Association in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) (American Psychiatric Association, 1994); the World Health Organization's International Classification of Diseases (ICD-10) (World Health Organization, 1992); and the National Institute of Neurological Disorders and Stroke, and the Alzheimer's Disease and Related Disorders Association's (NINCDS-ADRDA) (McKhann et al., 1984) criteria for clinical diagnosis of Alzheimer's disease.

Although each set of standards has its own specific criteria for the diagnosis of Alzheimer's disease, there are several factors shared among the three. These factors include; (1) an insidious disease onset, (2) the illness must be progressive and gradual, and (3) the existence of DAT must be the only cause of dementia. Further, in order to make the diagnosis of probable DAT it must be shown that the individual has impairments in at least two areas of cognition (e.g., memory, abstract thinking, word finding, object recognition). Other symptoms that may assist in the diagnosis of DAT, according to the NINCDS-ADRDA work group, are the absence of brain diseases or other disorders that could cause the progressive decline in cognition and memory, impaired activities of daily living, changes in behavior, an age of onset between 40 and 90 years (most commonly at or above the age of 65 years), or a progressive decline in other cognitive functions, such as language, motor skills, or perception (McKhann et al., 1984). Each of the three diagnostic tools are widely accepted, however, only the NINCDS-ADRDA allows for an individual to be categorized with differing levels of diagnostic certainty. Specifically, the NINCDS-ADRDA has incorporated into their classification criteria disease levels of definite, probable and possible dementia of the Alzheimer's type (McKhann et al., 1984).

ALZHEIMER'S DISEASE DIAGNOSIS: PHYSIOLOGICAL

To date, there are no markers with which to establish a definitive diagnosis of DAT, however, several techniques (e.g., neuropsychological, biochemical, neurophysiological) have been developed that assist in, and increase, the diagnostic precision with which physicians and researchers can accurately make a diagnosis of the dementing illness (Forsyth & Ritzline, 1998; Growdon, 1999). One technique that is used to identify the illness in the early stages is the detection of abnormal tau proteins in the cerebrospinal fluid (Forsyth & Ritzline, 1998; Growdon, 1999). The abnormal tau proteins have been shown to cause neurons to become tangled and cross linked in individuals with the dementing illness (Braak et al., 1999).

Some of the more common tests used to determine the presence of the structural changes in the brain of an individual with DAT include magnetic resonance imaging, single photon emission computed tomography, regional cerebral blood flow, positron emission tomography, and computerized axial tomography. The validity, reliability, and sensitivity of each of these diagnostic tests, however, have been questioned with regard to their ability to detect the hallmark changes of the dementing illness. However, when the information gained from physiological techniques is combined with psychological assessments, the certainty of DAT diagnosis increases (McKhann et al., 1984; Forsyth & Ritzline, 1998). Although their use does not guarantee an accurate diagnosis, the use of multiple diagnostic techniques can aid a physician or researcher in making a more accurate diagnosis of the illness.

Although the cause of DAT is uncertain, numerous investigations have identified several pathological changes occurring in the central nervous system of individuals' with the dementing illness. Two common characteristics of the illness are the formation and presence of neurofibrillary tangles and senile plaques in the cerebral cortex (Smith, 1998). Senile plaques predominantly occur in two main forms, those being diffuse and neuritic plaques (Morris, 1995). Both forms of the senile plaques are extracellular and can be found in varying densities throughout the neocortex of the brain of an individual with DAT. Conversely, neurofibrillary tangles are intracellular and typically occupy the cell body and portions of the dendrites of large pyramidal neurons, primarily those with long ipsilateral cortico-cortical connections (Morris, 1995; Braak et al., 1999). The formation of the neurofibrillary tangles results from the presence of pathological forms of tau proteins in the cerebrospinal fluid (Braak et al., 1999). These tau proteins cause the affected neurons to become tangled and cross-linked, and cause dendrites to become detached from the stem of the nerve cell (Braak et al., 1999). The earliest location for neurofibrillary tangle formation is in the transentorhinal and entorhinal regions of the brain that mediate neural impulses between the hippocampus and the temporal isocortex and play an important role in the processing of sensory information. As the disease progresses, the tangles penetrate the hippocampal formation, the amygdala, and the association areas of the neocortex (Braak et al., 1999). It is not until the later stages that tangles begin to appear in the primary motor and sensory cortices (Braak et al., 1999).

Although plaques and tangles are commonly associated with the illness, the frequency of their occurrence has been found to increase with age in both demented and non-demented individuals. As a result of the shared occurrence of plaques and tangles in both demented and non-demented brains, investigators have attempted to develop guidelines to discriminate between normal aging and the onset of DAT. Attempts have been made to develop a uniform methodology based on plaque density; however, as Morris (1995) points out, not all investigators have chosen to adopt the methodology, thereby limiting the number of comparisons that can be made between studies.

Since plaques and tangles can be found in the brains of both demented and non-demented older adults (Price, 1993; Crystal et al., 1993 Morris 1995), the presence of these pathologic structures is not sufficient to allow for a diagnosis of DAT. Researchers have speculated that the presence of plaques, and to a lesser extent tangles, in a non-demented brain may be indicative of pending DAT (Morris, 1995). The belief is that if the individual with plaques and tangles was to live into or, beyond the tenth decade of life, the proliferation of pathological changes would eventually result in a diagnosis of DAT. In light of the presence of plaques and tangles in the brains of several non-demented older adults, a number of researchers have reported an absence of the structural changes up to and beyond the age of 100 years (Andersen-Ranberg, Vasegaard & Jeune, 2001; Price, 1994). The fact that individuals can remain free of the hallmark signs of the dementing illness suggests that although the prevalence of the neurological changes associated with DAT increase as a function of age these changes are not inevitable.

In addition to the development of plaques and tangles, other changes occurring in the brains of individuals with DAT include neuronal death and a loss of synaptic connections in the cerebral cortex (Forsyth & Ritzline, 1998). One brain region that has been shown to experience a considerable loss of synaptic connections is the hippocampus (Ball, 1978). The severe degree of synaptic loss often times results in an actual disconnection of the hippocampus from the neocortex. This neocortical disconnection severely impairs the ability of DAT patients to acquire new information (Van Hoesen & Hyman, 1990; Morris, 1995), and has been shown to impair the integration of visual, auditory, and somatic information from the temporal, occipital and parietal lobes (Flood & Coleman, 1990; Van Hoesen & Hyman, 1990). The degree of disconnection evidenced in the hippocampus of individuals with DAT is suggested to be as disruptive to hippocampal function (both the input and the output of information) as hippocampalectomy (Van Hoesen & Hyman, 1990). In fact, the structural and functional changes occurring as a result of the illness have been suggested to result not only in a disconnection of the hippocampus, but also disconnection of the association cortices resulting in each region functioning in isolation (Morrison et al., 1990).

The hippocampus has been shown, however, to have a considerable degree of plasticity in an apparently healthy older-adult population in spite of the loss of neurons associated with increasing age. Researchers have determined that the level of plasticity is sufficient to sustain normal brain function in an apparently healthy older-adult population in light of the extent of neuronal loss (Flood & Coleman, 1990). The plasticity reported in apparently healthy older adults results from neuronal growth by means of increases in the length and number of dendritic segments (Flood & Coleman), These same changes, however, have not been evidenced in the brains of individuals with DAT. Rather, the brains of individuals with DAT have shown an overall loss in dendritic extent, suggesting an impairment of the dendritic proliferation normally seen in the brains of non-demented individuals (Flood & Coleman).

Individuals' with SDAT have also been shown to have neuronal changes in the brainstem (Aletrino, Vogels, Van Domberg & Ten Donneklaar, 1992). In addition to the changes in the hippocampus and brain stem, changes have also been evidenced in cortical and subcortical areas in the DAT brain including the development of neuropil threads, "...dense intraneuronal (probably intra-axonal) accumulations of paired helical filaments..." (Morris, 1995 p. 212), and an overall decreased brain mass (Berg, McKeel, Miller, Baty & Morris, 1993) when compared to age-matched apparently healthy adults. In spite of the structural changes that occur in the DAT brain the presence of the disease may go undetected, at least in the early stages, because individuals may be able to rely upon a reserve capacity that allows for a relatively high level of function to be maintained. Often times the first cognitive feature of the disease is some degree of memory impairment, and in some instances an individual may experience a personality change that is noticed by someone close to the individual (Morris, 1996).

Of the numerous risk factors associated with DAT (e.g., age, genetics, and environmental factors such as exposure to heavy metals) the presence of the apolipoprotein e4 allele (ApoE4) has received a great degree of interest in recent years (Weiner et al., 1999; Feskens et al., 1994; Jelic et al., 1997; Kalmijn, Feskens, Launer & Kromhout, 1997). Researchers have reported that individuals diagnosed with DAT are four times more likely to have the ApoE4 allele than those without the illness (Growdon, 1999; Weiner et al., 1999). Although the presence of ApoE4 increases ones' risk for developing DAT, many individuals with the allele are never diagnosed with dementia of the Alzheimer's type (Growdon, 1999). Additionally, the risk associated with ApoE4 has been shown to be age dependent, in that individuals with the allele are more likely to develop DAT between the ages of 65 to 75 than at other ages (Weiner et al., 1999; Frisoni et al., 1998). Although ApoE4 has not proven to be specific to individuals with DAT it can be used to increase the certainty of a diagnosis of probable DAT (Mayeux et al., 1998).

COGNITIVE AND MOTOR CHANGES IN SDAT

Impaired short-term memory is one of the earliest hallmarks of SDAT. Although some degree of forgetfulness is often times associated with 'normal' aging, its manifestation is quite different and far less devastating. Impairments occurring as a function of aging are usually intermittent in nature and often times related to trivial matters. An individual with age-associated memory impairments (also referred to as benign forgetfulness) retains the ability to remember important material, while the individual with SDAT will typically suffer impairments in both trivial and important information (Hamdy, 1998). Another significant difference between benign forgetfulness and dementia-related memory impairment is the impact dementia has on an individual's ability to perform instrumental activities of daily living (i.e., managing money, remembering appointments). Individuals suffering from benign forgetfulness will often times remember what was forgotten if they concentrate or place reminder notes in visible locations once they realize that they may have difficulties remembering things. It is important to differentiate the memory impairments associated with SDAT and those of benign forgetfulness, however, so that an individual in the early stages of SDAT can receive treatment that may slow the progression of the illness.

Even though an individual with SDAT may be experiencing difficulties with short-term memory there are other areas of memory that are preserved well into the progression of the dementing illness. One area of memory that is retained, at least early in the course of the progressive illness, is the ability to learn and retain motor skills (Deweer et al., 1994; Dick et al., 1996). This preserved ability to retain and acquire motor skills is in part due to the relative sparing of the primary sensory and motor cortices until the later stages of the illness (Van Hoesen & Damasio, 1987). With the ability to learn novel motor skills, despite the dementing illness, there is considerable optimism that intervention programs designed to improve motor function in a number of areas may help to delay functional dependence in this group. These intervention programs may target novel motor skills or could be designed for any number of activities of daily living including, but not limited to, bathing, eating, grooming, ambulating and transferring. The importance of this preserved ability to acquire and retain motor skills has the potential to lessen the time and financial burden placed on the individual with SDAT and their family or caregivers by facilitating functional independence through specifically designed intervention programs.

While motor function appears to be preserved until late in the progression of SDAT, several investigations have identified impairments in balance and gait in the early stages of the illness (MacLennan, Ballinger, McHarg & Ogston, 1987; Tanaka et al., 1995; Chong, Horak, Frank & Kaye, 1999). Regardless of dementia severity, Morris, Rubin, Morris & Mandel (1987) determined that the presence of SDAT was, in and of itself, an important risk factor for falling. The extent to which disease severity affects falls risk, however, is unknown. A number of investigations have attempted to ascertain the effect of disease severity on falling and postural control; however, the findings have been equivocal (Chong et al., 1999; van Dijk, Meulenberg, van de Sande & Habbema, 1993; Morris et al., 1987; Alexander et al., 1995). In addition to the presence of SDAT having a negative effect on balance, several additional risk factors have been identified that may account for the elevated falls risk in this population when compared to their apparently healthy age matched peers. Some of the risk factors identified for individuals with the dementing illness include the increased incidence of wandering, arthritis, toxic reactions to drugs, peripheral neuropathy, visual disturbances, a decline in vigor, and decreased strength (Brody, Kleban, Moss & Kleban, 1984; Buchner & Larson, 1987; Morris et al., 1987; Nakamura, Meguro & Sasaki, 1996). Several of these same risk factors, in addition to many more, have been identified in a non-demented older adult population, and numerous investigators have developed interventions designed to specifically target these risk factors in a effort to reduce the incidence of falls (Rose & Clark, 2000; Rose, 1997b; Perrin, Gauchard, Perrot & Jeandel, 1999; Messier et al., 2000; Bohannon & Leary, 1995). It is anticipated that many of these same interventions could potentially be used to decrease the risk of falling in individuals with dementia of the Alzheimer's type.

SENSORY CONTRIBUTIONS TO POSTURAL CONTROL

The ability to attain and maintain a position of upright stance requires appropriate functioning of at least one, but ideally all three, sensory systems responsive to balance (i.e., vision, vestibular, and somatosensation). The need for proper functioning in more than one system becomes increasingly important as either the quality and/or quantity of sensory information is altered. If the environment in which the individual is standing is stable (e.g., firm support surface and stable visual surround), it may be possible for the individual to maintain balance with the use of a single sensory system. However, if the environment is altered or changed in any way (e.g., moving, slippery, or compliant support surface, changing visual flow, or decreased light) the need for more than one sensory system is necessitated due the increased likelihood of falling (Peterka & Black, 1990; Tinetti et al., 1988, Woollacott, Shumway-Cook & Nashner, 1986). It is possible, however, for an individual to function with decreased sensitivity or the loss of one or more of the sensory systems (e.g., peripheral neuropathy, loss of vision,), because of the large amount of redundancy in the information that exists among the three systems.

The sensory information received from the three systems originates from a number of sensory organs throughout the body. The somatosensory system includes the information received from muscle spindles, golgi tendon organs, joint receptors, and cutaneous receptors distributed throughout the body (Shumway-Cook & Woollacott, 1995). The information acquired from these sensory organs, once processed at a cortical level, creates a direct link between the individual and his/her interaction with the environment. The vestibular system provides the individual with information relative to linear and angular movement of the head. The vestibular apparatus is comprised of three semicircular canals and two separate structures know as the saccule and utricle. The semicircular canals sense angular movement of the head, while the utricle and saccule are sensitive to linear movement. The third and final sensory system that provides information related to the maintenance of balance is the visual system. The visual system provides information relative to the movement of the environment, movement of the individual within the environment and movement of limbs and joints relative to the body (Rose, 1997a). When functioning properly, the three sensory systems provide the individual with several cues about the environment and the individual's movement within the environment.

Although each of the three sensory systems contribute unique sources of information relative to balance there is a considerable amount of redundancy between the three systems. It is a result of this overlap that an individual can maintain balance even in the face of permanent loss or the reduced function, in one or more of the systems. It is also as a result of this redundancy that an individual can maintain balance in situations of sensory conflict (e.g., standing at a curb with the perception of actual movement based on a bus moving away from the curb). When a situation arises in which one or more of the sensory systems are reporting inaccurate sensory information, relative to the interaction of the individual and the environment, the individual needs to attend to the remaining system or systems that are providing accurate positional information if balance is to be maintained (e.g., compliant support surface combined with movement of the visual field that is opposite to actual or desired body movement).

Afferent information from the peripheral visual, vestibular and somatosensory receptors is organized and then integrated in a number of regions of the brain. Two areas primarily responsible for this integration of balance related sensory information are the parahippocampal gyri and the parietal lobes of the brain (Van Hoesen & Damasio, 1987; Stein, 1985). The parahippocampal gyri are responsible for integrating information from the temporal, occipital, and parietal lobes regarding the state of the visual, somatic, and auditory systems, while the parietal lobes receive and integrate visual, and proprioceptive information with efferent motor signals. This ability to accurately and effectively couple perception and action is instrumental for an individual to successfully interact with their environment. It is also this integration and perception/action coupling that may be compromised in individuals with SDAT, and is the focus of this investigation.

COMPUTERIZED DYNAMIC POSTUROGRAPHY

Assessing sensory integration during the maintenance of upright stance is often conducted using computerized dynamic posturography (CDP). With the use of a force platform, movement in the A-P direction can quantify postural sway as a function of the forces exerted onto the support surface by contraction of the muscles of the trunk and lower extremities (Nashner, 1982a). Trunk and lower limb musculature is contracted in response to spontaneous shifts in the COG during upright balance that results from the natural instability of the human body. The shifts in the COG occur as a function of fluctuations that are both internal and external to the individual. In order to determine the integrity of the sensory systems used to maintain balance the support surface on which the individual stands can be sway-referenced to movement of the COG in the A-P direction. By synchronizing the movement of the support surface to movement of the COG, afferent information from the lower extremities is dramatically reduced. When an individual stands on the sway-referenced support surface, movement in the ankle joint is nearly eliminated (Nashner, 1982b), which in turn reduces afferent somatosensory information from the lower extremity, forcing the individual to utilize the unaltered visual and vestibular systems.

In addition to the sway-referenced support surface, CDP can also be used to reduce afferent information from the visual system, by sway-referencing the visual environment in a manner analogous to that of the support surface described above. By enclosing the individual in a sway-referenced room, that is capable of rotating in direct proportion to A-P movement of the COG, the visual environment appears to be stationary despite the actual displacement of the COG (Nashner, 1982b). When placed in this sensory environment the individual needs to utilize information from the unaltered somatosensory and vestibular systems if balance is to be maintained.

When sensory information regarding the location of the COG is reduced (by sway-referencing the support surface, the visual surround, or both), information from the vestibular system becomes more important to maintaining postural stability. The contribution of vestibulospinal reflexes to the maintenance of postural stability has been shown to change as a function of the availability and integrity of visual and somatosensory information (Welgampola & Coebatch, 2001). When visual and/or somatosensory information are absent or inaccurate the role of the vestibular system becomes crucial to the maintenance of upright stance. Welgampola and Coebatch have demonstrated that depending on the availability and quality of visual and somatosensory information, vestibulospinal reflexes increase in magnitude as the validity of the other sensory systems decrease. When the environment in which an individual is standing is stable and all sensory systems are providing accurate positional information, the magnitude of vestibulospinal reflexes decreases significantly. (Welgampola & Coebatch). When an individual is placed on a sway-referenced support surface, in the absence of vision or in a sway-referenced visual surround, the contribution of short loop and medium loop vestibulospinal reflexes (causing activation in postural muscles) is significantly larger than in situations where the somatosensory and/or visual systems are providing accurate positional information (Nashner, 1982a; Welgampola & Coebatch, 2001). Because the vestibular system is gravitationally referenced, and is relatively difficult to manipulate through environmental changes, its role in resolving sensory conflicts (i.e., both somatosensory and visual information are inaccurate) substantiates the vestibular system's importance in maintaining postural stability (Nashner, 1982b).

Computerized dynamic posturography has been used to assess balance difficulties in several different age groups (Ford-Smith, Wyman, Elswick, Fernandez & Newton, 1995; Peterka & Black 1990), and to distinguish and differentiate between numerous diseases including but not limited to Huntington's disease (Tian, Herdman, Zee & Folstein, 1992), Parkinson's disease (Toole, Park, Hirsch, Lehman & Maitland, 1996), Alzheimer's disease (Chong et al., 1999), and vestibular loss (Horak, Nashner & Diener, 1990). Although CDP does not provide a definitive diagnosis regarding the severity and location of disability in a sensory system, the use of CDP is highly effective in the detection of functional abnormalities and also in the design and evaluation of individualized balance retraining programs (El-Kashlan, Shepard, Asher, Smith-Wheelock & Telian, 1998). One word of caution has been suggested by Ford-Smith and colleagues, and is further supported by the work of Coogler (1996), indicating the need for repeated assessments to obtain reliable test results when using CDP. Due to the novelty of the environmental manipulations created by the SOT individuals need to become familiar with each of the six conditions before reliable test results can be obtained.

SUMMARY

Senile dementia of the Alzheimer's type is estimated to affect 10% of all individuals over the age of 65 years, and is the seventh leading cause of death in this age group in the United States (Forsyth & Ritzline, 1998; National Center for Health Statistics, 2001). The prevalence of SDAT has been found to double with every decade of life after the age of 65, affecting nearly one half of all individuals aged 85 years and older (National Institute on Aging, 1996). Current estimates suggest that approximately four million Americans have the illness, with this number expected to double every 20 years if no cure is discovered (National Institute on Aging, 1995). The first sign of the illness is impairment in short-term memory progressing to deterioration in activities of daily living, impaired language, increased agitation, wandering, and ultimately, a total loss of independence. In spite of the widespread losses, researchers have found regions of spared functions that exist at least until the late stages of the illness. Of interest to this investigation is the ability of individuals with the dementing illness to retain and acquire motor skills, in particular, the motor skill of balance. Although individuals with SDAT retain the ability to ambulate well into the progression of the illness, researchers have demonstrated an increased incidence of falling in this population (Buchner & Larson, 1987; Morris et al., 1987), which has been found to be four times greater than their apparently healthy older adult peers.

Several risk factors have been forwarded to account for the increased incidence of falling; however, only a few studies have attempted to explain the increased falls risk. Understanding the neuronal impairment associated with SDAT may help to uncover neurophysiological explanations for the elevated falls risk. Researchers have demonstrated a relative sparing of the primary sensory and motor cortices from the plaques and tangles associated with

Alzheimer's disease, which would intimate a preservation of motor and sensory function (Van Hoesen, 1982; Kemper, 1984; Stein, 1985). However, with the devastating changes occurring in the association cortices and the hippocampal region, the information provided to the primary sensory and motor cortices are likely to be considerably degraded. The contribution of the association cortices and the hippocampus to balance is of critical importance due to the involvement of these regions in the successful integration of sensory information necessary to maintain a position of upright balance (Smith, 1998). As such, it is possible that the increased falls risk in this population may, at least partially, be accounted for by the loss of integrity of the association regions of the brain.

Understanding the basis for the increased falls risk associated with SDAT is critical to the development of balance related intervention programs. Currently, however, there is a dearth of research attempting to explain this increased falls risk. Since it has been demonstrated that individuals with the dementing illness can learn and retain motor skills, it is hoped that by identifying the underlying cause(s) of the increased incidence of falling in this population that programs can be developed to reduce this risk and ultimately increase the amount of time that individuals with the illness can retain their functional independence.

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