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The Relationship between Hearing Status and Cognitive Performance and the Influence of Depressive Symptoms in the Older Adult

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by

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Dedication

This dissertation is dedicated to all of my past and present teachers. It is only because of their encouragement and mentorship, that I am finally fulfilling my dreams of becoming a nurse scientist and a mentor to future nurses.

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Abstract

Hearing loss and cognitive impairment are significant health problems, threatening the independent function of older adults. While there appears to be a strong relationship between the two conditions, the mechanisms underlying this association are complex and are not fully elucidated.

The purpose of this secondary analysis was to explore the relationship between hearing ability and cognitive performance in older adults. In addition, this study attempted to examine the role of depressive symptoms in the relationship between hearing loss and cognitive performance. Comprehensive measures of peripheral hearing, central auditory processing and cognitive performance were utilized to examine these relationships in a sample (N = 30) of adults aged 60 years and older. The Geriatric Depression Scale (GDS) was used to assess depressive symptoms.

Correlational analyses revealed a statistically significant relationship between central auditory processing and executive function. Statistically significant relationships were also observed between speed of processing and peripheral hearing as well as central auditory processing. No significant relationships were noted between depressive symptoms, hearing acuity and cognitive performance. While the correlation coefficients (*r*) for several of the hearing and cognitive performance measures were not statistically significant, medium effect sizes were detected, suggesting a moderate association may exist between these variables.

Chapter 1
Introduction

Background and Significance of the Problem

The fastest growing segment of the population are older adults, aged 65 years and older. According to a 2010 United States Census Bureau report, there are currently over 40 million adults aged 65 years or older, representing 13% of the total population (Werner, 2010). Consequently, maintenance of functional independence in the older adult through optimum health management is vital. Impaired cognition and hearing loss are two pervasive health problems that increase in prevalence with age (Gallacher, 2004; Lin, Thorpe, Gordon-Salant, & Ferrucci, 2011; Plassman et al., 2011). It is estimated that 1 in 3 adults aged 65 years and older have hearing loss (Hearing Loss Association of America [HLAA], 2013). Plassman et al. (2007) claim 13.9% of the adult population aged 71 years and older suffers from some level of cognitive impairment, ranging from mild impaired cognition to dementia. Hearing loss and impaired cognition often contribute to the loss of an individual's independent function (Agrawal, Platz, & Niparko, 2008; Vance, 2009). The social and economic implications associated with these conditions for the individual, their family and society are significant and growing. As a result, there is an urgent need to increase the clinician's understanding of how these conditions affect this segment of the population.

There is a strong link between hearing loss and cognitive impairment with adverse effects on the older adult's performance of daily activities including driving, ambulation and social

interaction (Lin et al., 2011; Lin et al., 2013; Lin et al., 2004; Wahl et al., 2013). In addition, impaired cognition and hearing loss are both related to depressive symptoms, diminished quality of life and are major contributors for institutionalization of the older adult. (Boi et al., 2012; Luppa et al., 2010; Sands et al., 2002; Spira, Rebok, Stone, Kramer, & Yaffe, 2012). However, the relationship between hearing loss and cognitive impairment is complex. Although several studies have clearly documented that hearing loss is independently associated with reduced cognitive functioning, the underlying mechanisms that link these conditions within the individual are not fully understood. Existing research in this area that has attempted to describe this relationship often examined only a single measure of hearing or assessed global mental status rather than cognitive performance, limiting the insight into the relationship of these conditions. There is a lack of evidence that has utilized both peripheral and central auditory measures along with multiple measures of cognition to attempt to characterize normal cognitive performance in older adults across various hearing levels. In addition, there is limited insight into the role of depressive symptoms and its potential impact on cognitive performance in older adults with hearing loss.

Currently, the majority of hearing loss (95%) can be effectively treated with hearing aids, hearing-assistive devices and aural rehabilitation (Sprinzl & Riechelmann, 2010). However, only about 20% of individuals who could benefit from amplification ever receive treatment (HLAA, 2013). One of the main barriers to treatment is the health care provider's underestimation of the negative physical and emotional impact of hearing loss in the older adult (Schneider et al., 2010). Lack of hearing screenings by healthcare providers, cost, and perceived stigma associated with hearing aid use are other factors that impede the treatment of hearing loss (Wallhagen, 2009).

Older adults with reduced cognitive performance who develop acute illness are at greater risk for long-term loss of daily functioning (Sands et al., 2002). Cognitive training interventions aimed at enhancing cognitive performance have been developed in the past decade. Studies reveal cognitive training may minimize the effects of cognitive aging by improving memory performance, processing speed and executive function (Greenaway, Duncan, & Smith, 2013; Greenaway, Hanna, Lepore, & Smith, 2008; Kinsella et al., 2009; Reijnders, Heugten and van Boxtel, 2013; Wang & Hsieh, 2013). Generalizability of the research in this area is limited due to small sample sizes; lack of comparison to a control group and significant variability of the intervention design. In addition, there is a paucity of evidence for the efficacy of these interventions in daily activities associated with living independently (Ball et al., 2002; Kinsella et al., 2009). No previous research has been designed to specifically look at the effect of both cognitive training and hearing rehabilitation on cognitive performance in older adults. Before interventions that address both conditions can be applied, additional research is needed to expand the understanding of the relationship between hearing loss and cognitive performance.

Depressive symptoms are a substantial negative consequence associated with hearing loss and cognitive impairment in the older adult (Boi et al., 2012; Brink & Stones, 2007; Gopinath et al., 2012; Jungwirth et al., 2011; Spira, Rebok, Stone, Kramer, & Yaffe, 2012). These symptoms are manifested in the older adult as agitation, social withdrawal, self-neglect and diminished ability to cope with illness (Sutin et al., 2013; Tanner, Martinez, & Harris, 2014). While the negative impact of depressive symptoms in the older adult is frequently discussed in the literature, no previous studies that have examined the relationship between hearing loss and cognitive performance have included measures for depressive symptoms.

Statement of the Problem

Hearing loss and cognitive impairment are significant health problems, threatening the independent function of older adults. There appears to be a strong relationship between the two conditions with deleterious effects on the older adults' performance of many everyday activities including driving, ambulation, and social interaction. Quality of life among older adults with hearing loss and cognitive performance may also be impacted. There is a paucity of research that characterizes cognitive performance in older adults across hearing levels using comprehensive measures of both hearing and cognition. Further, little is known about the influence of depressive symptoms on the relationship between hearing acuity and cognitive performance. This gap in literature needs to be addressed before interventions aimed at improving hearing and cognitive performance can be tested.

Purpose of the Study

The overall purpose of this study was to explore the relationship between hearing ability and cognitive performance in older adults. In addition, this study examined whether depressive symptoms play a role in the relationship between hearing loss and cognitive performance.

Specific Aims and Research Questions

The specific aims of this study were:

1) Explore cognitive performance across varying levels of hearing acuity in older adults.

    Research Question:

1. What is the relationship between hearing acuity and cognitive performance in older adults?

2) Explore the impact of depressive symptoms on the relationship between hearing acuity and cognitive performance.

Research Question:

2. What is the influence of depressive symptoms on cognitive performance in older adults with varying levels of hearing acuity?

Definition of Relevant Terms

The following terms are defined for the purposes of this study:

1. Hearing Loss: Auditory dysfunction arising from degeneration of peripheral auditory structures (outer ear, middle ear, cochlea) or central auditory processing nervous system (brainstem, midbrain, auditory cortex).
2. Cognitive impairment: A decrease in function in one or more multiple domains of cognitive function.

Significance to Nursing

As the population of older adults continues to rise, nurses will increasingly encounter older adults with cognitive impairment and hearing loss. It is apparent that the occurrence of these conditions can have detrimental effects on the patient's quality of life and ability to remain functionally independent. This study offers essential information on cognitive performance across varied levels of hearing and the role of depressive symptoms in the older adult. Nurse

researchers will be able to utilize this information in the future to test interventions aimed at optimizing hearing and cognitive function in this population. In addition, the counseling and education provided by nurses on the benefits of hearing rehabilitation and cognitive training interventions will promote successful aging, prolonged autonomy and enhanced quality of life in the older adult.

Chapter 2
Review of the Literature

This review of literature is a synthesis of existing research pertaining to hearing status and cognitive performance in the older adult. The proposed conceptual model, serving as the guiding framework for this exploratory study, is introduced and discussed. In order to understand the necessity of this project, it is important to understand the evidence provided by previous researchers that supports a link between cognition and hearing in the aging adult. First, hearing status of the older adult, including peripheral hearing loss and central auditory processing changes of the older adult, is reviewed. Second, cognitive performance, categorized as executive function, memory and processing speed, in the older adult is discussed. Third, the link between hearing loss and cognitive impairment is explored to emphasize the need for a more in-depth understanding of the interaction between these two conditions. Fourth, the role of depressive symptoms in the relationship between hearing loss and cognitive impairment is considered. This dissertation project helps to fill a gap in the literature by enhancing the understanding of the relationship between cognitive performance and hearing status in the older adult.

Conceptual Framework

Research is an organized process used to answer questions (Fawcett, 1999). A conceptual framework is a vital component of study design as it serves as a guide for the generation or testing of theories through research. In addition, it can be regarded as a map used by the researcher for

understanding the relationships among variables of interest (LoBiondo-Wood & Haber, 2002). For the purposes of this study, designed to explore the relationship between hearing status and cognitive performance in the older adult and also investigate the mediating effect of depression, a conceptual framework was developed (Figure 1).

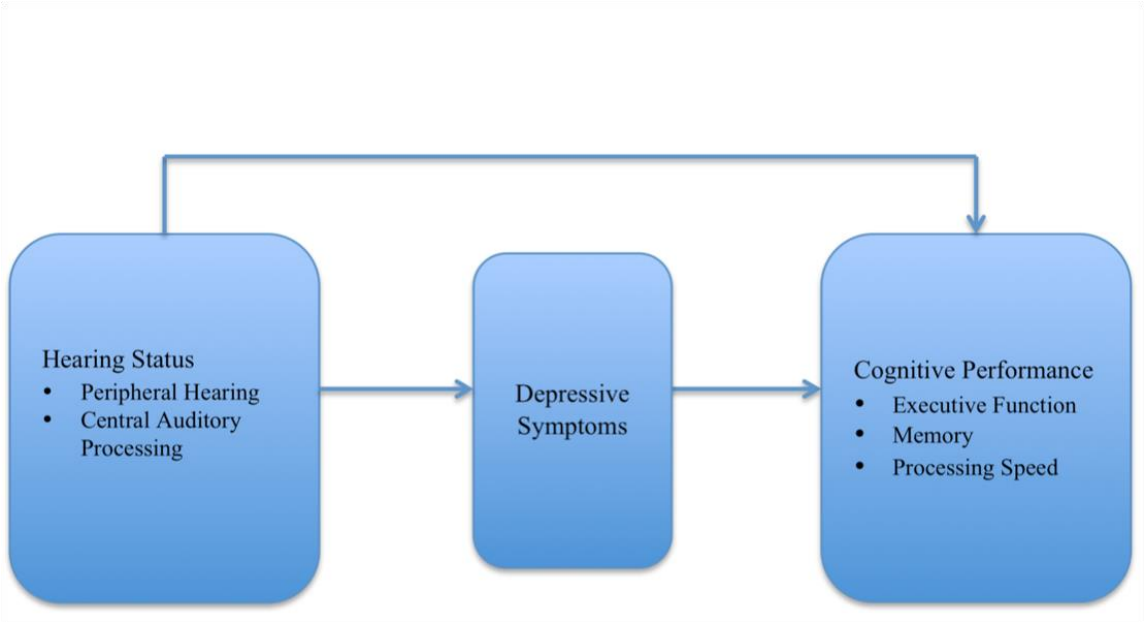

Figure 1. *Conceptual framework*

In this conceptual framework, hearing status (peripheral and central auditory processing) is purported to have a direct relationship with cognitive performance. Therefore, any hearing deficits in the older adult may affect their cognitive performance. In addition, depressive symptoms that are associated with hearing impairment may act as a mediator and influence cognitive performance.

Hearing Status

Hearing is a sensory function that is essential for optimal growth and development across the human's lifespan. It augments an individual's ability to interact with his or her surrounding environment, communicate with others and obtain information necessary for survival.

Unfortunately, as an individual ages, hearing acuity diminishes. Age-related hearing loss, also known as presbycusis, is the second most common chronic health condition in the older adult (Lee, 2013). According to Lin, Thorpe, Gordon-Salant and Ferrucci (2011), hearing loss is more prevalent in older men than women and occurs more frequently in white than black individuals. It affects the function of both peripheral and central structures of the auditory system (Gates & Mills, 2005; Laplante-Levesque, Hickson, & Worrall, 2010). Therefore, it is important to discuss peripheral hearing and central auditory processing impairments and it's impact on the older adult.

Peripheral Hearing

The auditory periphery is composed of the external, middle and inner ear including the cochlear and auditory nerve and is responsible for the encoding of sound input. In the older adult, degeneration in the peripheral auditory system, in addition to environmental assaults (primarily noise), genetics and medical co-morbidities (cardiovascular disease and diabetes) result in anatomic, physiologic and functional changes (Parham, Lin, Coelho, Sataloff, & Gates, 2013; Tun, Williams, Small, & Hafter, 2012). As a result, the older adult initially experiences a loss of pure-tone sensitivity, often greater in the high frequencies (Gates & Mills, 2005; Huang & Tang, 2010). While the individual may hear speech, their comprehension is reduced. The presence of even minimal background noise adds an additional challenge for the older adult (Lee, 2013). According to Lee, Matthews, Dubno and Mills (2005), hearing thresholds decline by approximately one decibel (dB) per year in individuals aged 60 years and older.

Central Auditory Processing

Central auditory processing (CAP), or sound decoding, occurs in the brainstem, midbrain and auditory cortex (Huang & Tang, 2010). The central auditory system is equally vulnerable to the same age-related anatomic and physiologic changes as the peripheral hearing structures. In the older adult, central auditory processing dysfunction affects speech discrimination, sound localization, temporal resolution and binaural processing (Gates & Mills, 2005; Humes et al., 2012; Tun, et al., 2012). The prevalence rate of CAP dysfunction has been estimated to be greater than 50% in the older adult population (Golding, Taylor, Cupples, & Mitchell, 2006; Stach, Spretnjak, & Jerger, 1990). Studies have compared the hearing ability of older adults (60 years of age and older) with younger adults. The results revealed the older adult, even those with normal or only mild hearing loss, had greater difficulty with speech discrimination, especially in the presence of background sound, suggesting an age-related central auditory processing dysfunction (Dubno et al., 2008; Mazelova, Popelar, & Syka, 2003; Smith, Pichora-Fuller, Wilson, & Macdonald, 2012).

Although hearing loss itself is not visible, the struggles experienced by an older adult when attempting to communicate with others are quite apparent. There are several negative consequences associated with hearing impairment in the older adult. The results of numerous primary studies suggest hearing loss, regardless of peripheral or central auditory origin, has a negative impact on socialization (Brink & Stones, 2007; Gopinath, et al., 2012; McMahon et al., 2013); the performance of daily activities, such as driving; (Gopinath et al., 2012; Green, McGwin, & Owsley, 2013; Hickson, Wood, Chaparro, Lacherez, & Marszalek, 2010; Strawbridge, Wallhagen, Shema, & Kaplan, 2000) and health-related quality of life. (Chia et al., 2007; Kelly-Campbell & Atcherson, 2012). Hearing loss even threatens physical safety

(Nachtegaal et al., 2009; Pronk, Deeg, & Kramer, 2013). Further, as hearing loss progresses in the older adult, social isolation increases and may hinder an individual from seeking treatment (Mick, Kawachi, & Lin, 2014).

The hearing status of the older adult has been studied using a variety of cross-sectional and prospective design methods with audiometric measurements and self-report questionnaires. The majority of existing research reporting the prevalence of hearing loss in the older adult only obtained peripheral hearing measurements (pure-tone thresholds) in various testing conditions. Large epidemiological studies have been conducted in older adults finding variable prevalence rates of hearing loss ranging from 16.1% to 63.1% (Agrawal, Platz, & Niparko, 2008; Cruickshanks et al., 1998; Lin, Thorpe, Gordon-Salant, & Ferrucci, 2011). Limitations of these studies include inconsistent definitions of hearing loss, the use of a cross-sectional design, and offering only between-age group differences. Further, these studies reduce the ability to quantify the amount and rate of change in hearing in an individual.

Several investigators in this area of research claim the data provided by audiometric testing (pure-tone thresholds) is limited. While it provides a measure that may reflect the degenerative changes in the auditory system, it does not offer data about hearing loss in everyday situations or the extent of the handicap caused by hearing loss (Saito et al., 2010). Therefore, they advocate the use of self-report measures as an adjunct to the traditional audiogram to aid in hearing assessment. The Hearing Handicap Inventory (HHI), evaluates self-perceived hearing handicap (Newman, Weinstein, Jacobson, & Hug, 1990). Data from two longitudinal surveys concluded the HHI is a measure not only for the detection of hearing impairment but may also predict future depression and social isolation in the older adult with hearing loss (Gopinath et al., 2012; Saito et al., 2010). In contrast, Hidalgo et al., (2009) reported the HHI was less sensitive

than audiometric measures when screening for hearing loss. However, the audiometric criteria they used for their study was a threshold level ≥ 40 dB at 1 and 2 kHz, excluding individuals with mild hearing impairment.

Fewer studies have included measures of central auditory processing such as the Synthetic Sentence Identification with Ipsilateral Competing Message test or the Dichotic Digits test (Gates, Anderson, McCurry, Feeney, & Larson, 2011; Gates, Beiser, Rees, D'Agostino, & Wolf, 2002; Gates et al., 2010; Lee, et al., 2005). However, the generalizability of the results to other populations of older adults is often limited by smaller sample sizes, failure to report ethnic dispersion of the study population and a lack of repeated measures.

Cognitive Performance

According to Vance (2009), optimal cognitive performance is vital for successful aging. In the older adult, cognitive performance is needed to sustain general health, daily functioning and active social engagement. In addition, it is required for an individual to remain in their independent dwelling (Luppa et al., 2010). Cognitive performance encompasses several domains. For the purposes of this study, the domains of executive function, memory and processing speed will be discussed.

Executive function

Executive functioning is described in the literature as goal-oriented, deliberate thought and action or "cognitive control." It is comprised of several constructs including selective attention, inhibitory control and working memory (Weintraub et al., 2013; Zelazo, Craik, & Booth, 2004). These skills are required for speech comprehension in the presence of background

noise. Formative literature in cognition claims executive function develops rapidly during childhood and adolescence but declines during aging (Salthouse & Meinz, 1995). Researchers have observed an association between reduced executive function and central auditory dysfunction in older adults (Gates et al., 2010; Hommet et al., 2010; Lin, 2011). Even minor attentional process impairment can diminish an older individual's ability to understand speech in noise (Tun, Williams, Small, & Hafter, 2012). There are several other negative consequences associated with executive function deficits and impaired central auditory processing in the older adult, most importantly safety. Recent longitudinal studies in older adults have observed slower gait speed in individuals with executive function deficits and have linked executive function decline to an increased risk for falls (Mirelman et al., 2012; Watson et al., 2010). In another study, Hickson et al. (2010) observed that older adults with hearing impairment had poorer driving performance in the presence of auditory distractors compared to those with normal hearing.

Working memory, a component of executive function, is the limited-capacity actions that allow an individual to simultaneously process and manipulate information during tasks and then retain the information for a short time. It is essential for speech processing in the presence of background sound (Ng, Rudner, Lunner, Pedersen, & Ronnberg, 2013). Research demonstrates working memory increases considerably in children, and remains stable over adulthood (Weintraub et al., 2013). However, a recent study observed greater diminished working memory processes in older adults with hearing loss in noisy compared to quiet listening conditions (Mishra, Stenfelt, Lunner, Ronnberg, & Rudner, 2014). Interestingly, Zekveld, George, Houtgast and Kramer (2013) demonstrated that individuals with better spatial working memory (SWM)

more frequently reported subjective hearing difficulties. These results suggest that older adults with better SWM may be more inclined to recognize their hearing impairment.

Processing Speed

Speed-of-processing has been described as the rate in which sensory input is sent to the brain, processed and reacted upon via motor responses (Vance, 2009). In the diminished *speed-of-processing theory,* Salthouse (1995) hypothesized that slowed processing speed mediates cognitive impairments in the older adult. Subsequent studies of older adults with hearing impairment have substantiated this hypothesis (Clay et al., 2009; Gates, et al., 2010; Jungwirth et al., 2011). Slowed processing speed and sensory function decline pose daily challenges for the older adult as they negatively impact their ability to socialize, drive, complete intellectual tasks and practice health-promoting behaviors (Vance, 2009).

Memory

Memory is the process of information storage and retrieval. In particular, episodic memory involves encrypting experiences related to a specific period of time. It is the brain's interface with reality (Weintraub et al., 2013). In the older adult, episodic memory is an early and sensitive indicator of neurodegenerative disorders, such as dementia and Alzheimer's disease (Haan & Wallace, 2004; Thies & Bleiler, 2013). Research has revealed that central auditory function is affected by memory impairment (Gates, Anderson, Feeney, McCurry, & Larson, 2008). Further, Jupiter (2012) found a positive correlation between hearing and scores on the Mini Mental Status Examination (MMSE) in a sample of nursing home residents.

Hearing Loss and Cognitive Impairment

It has been well established that the older adult is at increased risk for cognitive impairment and hearing loss. Galton first discussed the relationship between sensory impairment and cognitive decline over a hundred years ago (Clay et al., 2009). Contemporary research has corroborated this association, linking peripheral hearing loss with cognitive impairment in the older adult (Lin, 2011; Lin et al., 2011). In a recent longitudinal study, Lin et al. (2013), claim cognitive decline is accelerated in older adults with peripheral hearing loss. However, a major limitation of these studies is the use of a single measure of hearing by averaging pure-tone frequencies (0.5, 1, 2 and 4 kHz) in the better hearing ear (Lin, 2011; Lin et al., 2011; Lin et al., 2013). Further, this single measurement was obtained only at baseline and does not fully represent the higher frequencies, often decreased in older adults. Also, they measured cognition with 3MS, a measure of global cognition along with only a single measure of executive function. Interestingly, Gates et al. (2010) did not find an association between peripheral hearing loss and cognitive impairment. However, they did observe an association between central auditory processing dysfunction and reduced cognitive performance. It is important to point out that this study only used a global measure of mental status rather than specific tests for the various domains of cognitive performance.

While several theories have been used to elucidate the observed relationship between hearing loss and cognitive impairment, overdiagnosis of hearing loss and cognitive impairment needs to be considered in all trials exploring this association. Older adults with hearing loss frequently experience difficulty with verbal communication. They may either fail to hear or may misunderstand the instructions given by the examiner during cognitive testing. Further, individuals with cognitive impairment may not accurately respond during audiometric testing not

because they don't hear the frequency tones, but because they do not understand how to respond. This may result in an overdiagnosis of cognitive impairment in older adults with hearing impairment or hearing loss in individuals with cognitive impairment (Lin, 2011; Lin, Metter, et al., 2011). Eligibility criteria that includes screening measures for hearing and cognition is essential to minimize the risk of over diagnosis.

Recent evidence from a longitudinal study has suggested that central auditory processing dysfunction may be an antecedent of Alzheimer's disease (Gates et al., 2011). Unfortunately, hearing loss in the older adult is gradual and it takes about 10 years for an individual to recognize the impairment (Bennion & Forshaw, 2012; Davis, Smith, Ferguson, Stephens, & Gianopoulos, 2007). In addition, hearing loss is often not addressed by primary care providers during routine physical examinations (Cohen, Labadie, & Haynes, 2005; McMahon et al., 2013). In the case of Alzheimer's disease, a diagnosis of hearing loss may aid in early identification, treatment and hopefully delayed disease progression. It seems apparent there is a lack of longitudinal studies that have explored the relationship of hearing loss and cognitive impairment using comprehensive measures of hearing and cognitive performance.

Depressive Symptoms, Hearing Loss and Cognitive Impairment

Epidemiological evidence reports prevalence rates for depressive symptoms ranging from 15% to 37% in older adult populations (Meeks, Vahia, Lavretsky, Kulkarni, & Jeste, 2011; Rodda, Walker, & Carter, 2011). Specifically, Li et al. (2014) estimated moderate to severe depression prevalence rates of 11.4% in older adults with at least mild hearing impairment compared to 4.9% in older adults without hearing impairment. Several studies report a strong correlation between hearing loss and depression in the older adult (Abrams, Barnett, Hoth,

Schultz, & Kaboli, 2006; Brink & Stones, 2007; Gopinath, et al., 2012) and have even observed an improvement in depressive symptoms following the treatment of hearing loss with hearing aids (Acar, Yurekli, Babademez, Karabulut, & Karasen, 2011; Boi et al., 2012). In addition, recent evidence suggests depression is also associated with impaired cognitive performance (Jungwirth et al., 2011; Spira, Rebok, Stone, Kramer, & Yaffe, 2012). However, the underlying mechanisms that link these conditions are not well understood. No prior studies that have examined the relationship of hearing loss and cognitive performance have included measures for depressive symptoms. Due to the substantial negative consequences associated with depressive symptoms, it is important to understand the role of depressive symptoms and its impact on cognitive performance in older adults with hearing loss.

Summary

This review of the literature provided an overview of the relationship between hearing status and cognitive performance in the older adult. In addition, it offered a synthesis of the evidence for the link between hearing loss and cognitive impairment, supporting the need for this secondary data analysis. There is a vital need for additional evidence to advance the healthcare provider and patients' understanding of the impact of hearing loss on cognitive performance. It is clear there is a paucity of studies that explore the relationship of hearing status and cognitive performance in the older adult using comprehensive measures of both hearing and cognition. The use of comprehensive measures for both hearing and cognitive performance, in addition to self-report measures for depressive symptoms in this exploratory study adds evidence to enhance the understanding of the relationship between hearing status and cognitive performance as well as the role of depressive symptoms in the older adult.

Chapter 3
Methods

This chapter provides a detailed description of the procedures that were utilized to meet the specific aims of this exploratory study. First, the study design is outlined. Second, a description of the setting and study participants will be presented. The criteria for participant inclusion and exclusion are also reviewed. Third, the instruments selected for this proposed study are reviewed. Fourth, the study procedures including approvals, subject recruitment, informed consent and data collection are explained. Last, the procedures for data analysis are described.

Study Design

An exploratory secondary analysis of existing data was planned for the present study. Data were obtained from a larger parent study "The Relationship between Visual Status and Cognitive Performance in Older Adults," conducted by Dr. Amanda Elliott. The parent study utilized a correlational, cross-sectional design.

Population, Setting and Sample

Adults aged 60 years and older were recruited through physician referral by medical staff at the University of South Florida (USF) Eye Institute, and from an existing patient registry obtained from the USF Cognitive Aging Lab. In addition, advertisement flyers were distributed in the waiting areas at the Eye Institute. Individuals interested in participation completed a

contact card and placed it in a collection box in the waiting area. Data collection for the vision testing, cognitive performance measures and the demographic questionnaire was performed at the USF Eye Institute. The auditory testing and depression screening were conducted at an auditory research laboratory, located in USF's Department of Communication and Sciences and Disorders. The laboratory is supervised by Jennifer Lister, Ph.D., CCC-A, FAAA. In the parent study, a total of 50 older adult participants completed the vision and cognitive performance measures. These participants were then contacted by telephone after completion of the initial study appointment and recruited to attend a second visit to complete hearing testing and depressive symptom screening. A subgroup of 30 subjects also completed hearing testing and a self-report questionnaire for depressive symptoms. This dissertation project focused on data analysis of subjects within this subgroup.

The sample size in the parent study was determined based on adequate power to detect "medium" effect sizes between individual measures of hearing and cognitive performance. In bivariate analyses, a sample size of 35 subjects was estimated to provide 80% power, assuming 2-sided type 1 error rate of .05 to detect a non-zero correlation coefficient of .45 or higher.

Inclusion and Exclusion Criteria

Eligibility criteria for the parent study included adults: 1) 60 years of age or older, 2) able to understand, read and speak English, 3) with pure tone hearing threshold for 2 frequencies (1 & 2kHz) <70 decibels (dB) in both ears, 4) with a score of 22 or higher on the Montreal Cognitive Assessment. Individuals with near vision worse than 20/200 while wearing their habitual correction were excluded, as this prevented completion of the computerized cognitive

performance testing. Also, an individual with any disability or health condition (i.e. aphasia) that prohibited completion of the study assessments were excluded from study participation.

Instruments

The measures selected for this secondary data analysis were categorized as: inclusion to determine eligibility for the study, hearing status (peripheral hearing, central auditory processing and tympanometry), cognitive performance, depressive symptom assessment and demographic/general health questionnaire. A detailed description of each measure is presented below. In addition, a summary of the hearing and cognitive performance measures included in this analysis is presented in Table 1.

Inclusion

Pure-tone hearing thresholds. Using standardized, manual pure tone audiometry, pure tones are delivered at 1 and 2 kHz. The participant's minimum threshold as measured in decibels (dB) for the two frequencies are recorded (American Speech-Language-Hearing Association, 2005). For inclusion in the parent study, participants were required to have a pure tone-hearing threshold for 2 frequencies (1 & 2kHz) less than 70 decibels (dB) in both ears, which would exclude individuals with severe-profound hearing loss. The typical clinical protocol for manual pure tone audiometry is based on a 5-dB step size for signal level variation. Jerlvall and Arlinger (1986) compared 5-dB and 2-dB step sizes in a group of individuals with moderate hearing loss and a group with normal hearing over two testing sessions. They found high mean correlation coefficients between the two sessions for both the 5-dB and 2-dB step sizes (r = 0.84 and 0.96), offering evidence of test-retest reliability.

Montreal Cognitive Assessment (MoCA). The MoCA is a brief cognitive screening instrument developed to assess cognitive impairment. As a global measure of cognition, it measures several cognitive functions including, executive function, short-term memory, language, attention, working memory and temporal and spatial orientation (Nasreddine et al., 2005). Each task is weighted differently for scoring. The total possible scores range from 0 to 30, with higher scores indicating better cognitive performance. In the parent study, a score of 22 or greater was required for participant inclusion. The MoCA takes approximately 10 minutes for completion. Freitas, Simões, Marôco, Alves and Santana (2012) provided evidence of construct validity using confirmatory factor analysis. The correlations between each cognitive domain and the total score for the MoCA were positive and high (r = .77-.80). Internal consistency reliability ($\alpha = 0.83$) has been demonstrated (Nasreddine et al., 2005). See Appendix A for Montreal Cognitive Assessment.

Hearing Status

The instruments used by the parent study for data collection during the peripheral hearing and central auditory processing testing session are displayed in Appendix B.

Peripheral Hearing

Pure-tone hearing thresholds, air & bone conduction (R_std_PTA, L_std_PTA, R_HF_PTA, L_HF_PTA). According to the Guidelines for Manual Pure-Tone Threshold Audiometry (American Speech-Language-Hearing Association, 2005), manual audiometry is the benchmark for the assessment of hearing status in the clinical setting. Using a standardized protocol and calibrated equipment specific for manual pure tone audiometry, a tester (usually an

audiologist) delivers a series of tones across eight frequencies (.25, .50, 1, 2, 3, 4, 6, 8 kHz). Tone detection is used to determine the individual's hearing sensitivity, measured in decibels (dB), for each frequency in each ear. The results are recorded on an audiogram chart or graph. Testing is completed in approximately 20 minutes. Although the equipment is calibrated, differences in measurement methods may affect validity and reliability. The use of a standard testing protocol minimizes inter-test differences (American Speech-Language-Hearing Association, 2005). Test-retest reliability for pure-tone hearing thresholds was previously discussed in the section describing inclusion criteria. For the purposes of this study, a pure-tone threshold average (PTA) of the frequencies .50, 1 and 2 kHz (standard PTA) and 4, 6, and 8 kHz (high-frequency PTA) for each ear was calculated to quantify the hearing level of each participant. Hearing status was categorized as: (a) no hearing loss, with PTA between 0 and 25 dB; mild hearing loss, with PTA between 26 and 45 dB; moderate hearing loss, with PTA between 46 and 65 dB and severe hearing loss, with PTA greater than 65 dB.

Tympanometry (Tymp). Acoustic tympanometry testing is used to evaluate the tympanic membrane, middle ear compliance, pressure and gradient. Using a calibrated machine (tympanometer), the tester inserts a small probe in the ear canal and the machine delivers a slight pressure to the tympanic membrane. Recordings are captured which quantify tympanic membrane movement and middle ear air volume and plotted as a tympanogram. The test takes about 1 minute to complete and the results are categorized according to the shape of the plot, as Type A, B or C. Type A is indicative of normal eardrum and middle ear function. Type B and C plots indicate compromised eardrum movement or increased middle ear pressure (Wiley & Block, 1979). In a previous study, Fishpool, Kuhanendran, Swaminathan and Praveen (2009)

assessed the predictive validity of tympanometry in a group of pediatric patients. Sensitivity (r = 0.73) and specificity (r =0.84) was high for tympanometry detecting a middle ear effusion.

Words-in-noise (WIN). The WIN test measures an individual's speech comprehension in a noisy background environment. The test uses several signal-to-babble (S/B) ratios ranging from 0 to 24 dB. Headphones are placed over an individual's ears and a recorded voice delivers two sets of 35 single words in the presence of the various S/B ratios. The individual is instructed to repeat the words to the tester. The background noise gets increasingly louder as the test progresses. Scores are recorded as the total percent of correct words and the dB signal-to-noise (S/N) threshold, with the possible score range 0 to 100 % correct words, or -2 dB S/N to 26.0 dB S/N threshold (Wilson & Burks, 2005). A lower dB S/N threshold indicates better performance. WIN testing can be completed in 5 minutes. Speech recognition performances of individuals in S/B ratios were compared to performances in speech-spectrum noise in a previous study. The results showed similar performances among participants, providing evidence of criterion validity (Wilson, Carnell and Cleghorn, 2007). Wilson and McArdle (2007) administered the WIN test to a cohort of older veterans at two different sessions (12 months apart). In addition, high test-retest reliability was revealed, with an intra-class correlation of (r = 0.88).

Central Auditory Processing

Time compressed speech (TCS45, TCS65). Central auditory processing speed is evaluated with accelerated speech. A recording of 50 words delivered by a female speaker via headphones at 45% and 65% compression is administered to an individual binaurally under standardized audiometric testing conditions. TCS is scored as the percent of correct responses of the words repeated back to tester and a possible score ranges between 0 and 100. Lower scores

indicate poorer speech recognition. The test takes 10 minutes to complete (Wilson, Salomon, Sperry, & Bornstein, 1994).

Synthetic Speech Identification with Ipsilateral Competing Message (SSI-ICM). Monaural speech perception is measured with SSI-ICM testing. Headphones are placed over the ears of the participant, and a grammatically correct, yet meaningless sentence (e.g. go change your car color is red) as well as a meaningful narrative is simultaneously delivered to the same ear at the same sound level. The participant must identify the sentence that was presented from a list of 10 sentences (Speaks & Jeger, 1965; Feeney & Hallowell, 2000). The SSI-ICM is scored as the percent of correctly identified sentences and a score of 80% or more is considered normal performance. Poor performance may be a predictor of cognitive impairment (Gates et al., 1996; Gates, Beiser, Rees, Wolf & D'Agostino, 2002; Gates, Anderson, Feeney, McCurry & Larson, 2008). Parallel-test reliability (r = 0.93) was estimated (Dubno, J., & Dirks, D.,1982).

Dichotic Sentence Identification (DSI). DSI assesses binaural speech processing. The same synthetic sentence stimuli as the SSI-ICM is used. However, one single sentence is presented to one ear and a different sentence is simultaneously delivered to the opposite ear. In the DSI, the participant must identify both sentences from a list of 10 sentences and it is scored as the percent of sentences correctly identified (Fifer, Jerger, Berlin, Tobey & Campbell, 1983). In adults, a score of 80% or above is deemed normal performance. Studies of older adults with Alzheimer's disease (AD) have provided evidence of test-retest reliability (r = .79 - .97) and poor performance may be a predictor of cognitive impairment, supporting construct validity (Gates, Cobb, Linn, Rees, Wolf & D'Agostino, 1996; Gates, Beiser, Rees, Wolf & D'Agostino, 2002; Gates, Anderson, Feeney, McCurry & Larson, 2011).

Dichotic Digits test (DDT). In the DDT, numbers between one and nine (excluding seven) are used. Two pairs of numbers are presented to each ear at the same time. The participant is instructed to repeat all four numbers aloud. A total of 25 sets of numbers are used and is scored as the percent correct. Scores 90% or above indicate normal performance in adults (Musiek, 1983; Kimura, 1961). Studies have evaluated the DDT for test-retest reliability (r = .79 - .97) in older adults with and without AD (Strouse & Hall, 1995). In this study, the DDT will be used in a population of individuals without AD.

Hearing Handicap Inventory (HHI). The screening version of the HHI is a 10-item, self-report questionnaire used to identify hearing-related activity limitations. It contains two subscales: emotional and social/situational and each is represented by five questions. Respondents answer "yes" (4 points), "sometimes" (2 points) and "no" (0 points). The total possible score range is 0 to 40. There is a screening version for use in individuals aged 18 to 65 years and a separate version for older persons over 65 years of age (Zecker et al., 2013). In the parent study, both versions of the HHI (as part of the Sensation battery of the NIH Toolbox) were utilized. Previous research has demonstrated high internal consistency reliability (α = 0.85 to 0.93) for both the total scale and subscales (Newman, Weinstein, Jacobson & Hug, 1990).

Cognitive Performance

The parent study used selected tests from the cognitive performance battery of the National Institute of Health (NIH) Toolbox. Additional tests of relevance were also used and are described below. The tests are categorized according to the domain they evaluate including executive function, processing speed and memory. Psychometric adequacy for the cognition battery of the NIH Toolbox was evaluated in English (N = 476). Test-retest reliability of the NIH

Toolbox revealed high interclass correlation coefficients (ICC) for the sub-domains of cognitive performance (ICC = 0.82-0.96). In addition, convergent validity (r = .48 to .93) and discriminant validity (r = .05 to .30) were estimated (Weintraub et al., 2013). See Appendix C for NIH toolbox information and cognitive performance instruments.

Executive Function

Controlled Oral Word Association Test (COWAT). The Controlled Oral Word Association test utilizes creative and strategic retrieval as well as monitoring of performance, mechanisms of executive function (Lezak, 1995; Parker & Crawford, 1992). In this test, participants are instructed to verbally produce as many words as possible beginning with three letters (C, F, and L). They are given 60 seconds for each letter. The score is the total number of words from all three trials. Higher scores indicate better performance. Ruff, Light and Parker (1996) provided evidence for test-retest reliability (r = .74).

Trail Making test A and B (Trl_A, Trl_B). Trail Making Tests are used to assess a number of cognitive functions including processing speed, attention and cognitive flexibility (Bowie & Harvey, 2006; Salthouse, Atkinson & Berish, 2003; Strauss, Sherman & Spreen, 2006; Tombaugh, 2004). While both tests A and B are taken on paper with pencil, each requires the participant to connect a different series of 25 inscribed circles, arranged in a semi-random manner, in increasing and/or alternating order. Test A primarily measures processing speed and contains circles with the numbers 1 through 25. Participants must connect in the numbers in increasing order (Bowie & Harvey, 2006). Test B contains both numbers and letters. The participant must also connect in increasing order with the added task of alternating between numbers and letters (e.g. 1→A→2→B→3…etc.). This second test requires attention shifts

necessary to complete the task correctly. Therefore, it is used as an indicator of cognitive flexibility. The test takes 10 minutes to complete. Scores are recorded as the time in seconds required to complete each task or may also be reported in the form of a ratio (i.e. B:A) or the difference of the two tests (i.e. B-A). Lower scores are indicative of better performance. Because of this recording method, participant errors are not reported as such, rather whenever a participant does connect two circles in an incorrect order, the examiner will make them aware of the mistake and revert them to their position just prior to the error. This allows for mistakes to be included within the total time needed to complete the tests (Bowie & Harvey, 2006; Strauss, Sherman & Spreen, 2006). While previously published studies have used the trail making A test to assess speed of processing, the present study utilized both trail making A and B tests as measures of executive function.

Processing Speed

Pattern Comparison Processing Speed test (PCPS). The Pattern Comparison test is part of the NIH Toolbox Cognition battery and utilizes a computerized format. It assesses choice reaction time (Weintraub et al., 2013). Participants are presented with two visual patterns and instructed to indicate whether the patterns are the same or different using designated keys on the keyboard. Participants have 90 seconds to answer as many questions as possible. Scores are recorded as the number of correct answers, out of a possible 130, given within the given time limit. Higher scores signify better performance. The test takes 3 minutes to complete (Weintraub et al., 2013).

Adaptive Test of Temporal Resolution (ATTR_AC, ATTR_WC). The ATTR uses a computerized format to measure the threshold at which the gap is sufficiently wide to be heard as

two sounds, also known as the gap detection threshold (Lister, 2011). Moreover, it assesses an individual's capability to follow the changes in the frequency and intensity of sound over time (temporal resolution). In this test, two short intervals of sound are presented, one containing a silent gap and one that is continuous. The participant is asked to identify the interval that contains the gap. It utilizes both within channel (WC; sounds before and after the gap are of the same frequency) and across channel (AC; sounds before and after the gap are of two different frequencies). As the program progresses it adapts by shortening and lengthening gaps in order to determine the limits at which the participant can detect them. The test takes 15 minutes to complete. Scores are reported as the geometric mean of the detectable gap lengths in milliseconds (ms). Higher scores are indicative of poorer performance. Test-retest reliability (r = .58-.87) was assessed in several studies (Lister, Besing & Koehnke, 2002; Lister, Koehnke & Besing, 2000; Lister & Roberts, 2005; Lister, Roberts, Shackelford & Rogers, 2006). For the purposes of this study, the ATTR was used to assess speed of processing. However, previous researchers have utilized this test as a measure of central auditory processing.

Memory

Rey Auditory Verbal Learning test (RAV_I, RAV_D). The NIH Toolbox also includes the AVLT. It assesses memory in the auditory modality (Weintraub et al., 2013). This task involves auditory presentation of a list of 15 unrelated words. The participant is instructed to provide both immediate and delayed recall of the words. The task is repeated three times. In addition, the parent study added a delayed recall trial assessed 20 minutes after the immediate recall trials. The test requires 10 minutes for completion. Two scores are computed: one for the

total number of words recalled during the immediate trials and a separate score for the delayed trial. Higher scores signify better performance.

Depressive Symptoms

Geriatric Depression Scale (GDS). The GDS is a self-report assessment using 15-items to identify depressive symptoms in the elderly. Using a paper/pencil format, respondents choose "yes" or "no" to answer each question and there are 15 possible total points (Burke, Roccaforte, & Wengel, 1991). Scores are categorized as (a) no depressive symptoms (0 to 4), (b) mild depressive symptoms (5 to 10) and severe depressive symptoms (11 to 15). The GDS takes 5 minutes to complete. Conradsson et al., (2013) evaluated the internal consistency of the GDS in older adults with and without cognitive impairment (α = .64-.82). In addition, they provided evidence for criterion validity as they revealed statistically significant correlations (r = -.59 to .73, $p < .05$) between the GDS and the Philadelphia Geriatric Morale Scale (PGCMS). The GDS is displayed in Appendix D.

Demographics

A paper/pencil demographic questionnaire was administered to each participant. The questionnaire obtained information including age, gender, education level, marital status and co-morbid medical conditions. The present study utilized a portion of this existing, de-identified data from the parent study. See Appendix E for demographic/general health questionnaire.

Procedures

Dr. Amanda Elliott, the principal investigator of the parent study granted permission for the use of the data included in this secondary data analysis.

Institutional Review Board (IRB)

IRB approval was sought for this exploratory study. The IRB application was submitted as an amendment under the parent study and received expedited approval. The IRB approval letter is exhibited in Appendix F.

Recruitment/Informed Consent

In the parent study, recruitment was initiated following USF Institutional Review Board (IRB) approval. Study personnel contacted prospective subjects via telephone for participation. Only research assistants and investigators that completed human subjects training and were approved by the USF IRB obtained informed consent and conducted testing. Participants completed the informed consent process at each testing appointment and unique informed consents were obtained for the two testing appointments prior to the initiation of data collection. In the parent study, each section of the informed consent was reviewed with the prospective participant and they were provided with an opportunity to ask questions prior to signing the consent. In addition, participants were encouraged to take time to consider whether they wished to participate in the study. Study personnel witnessed their signature and they received a full copy of the signed informed consent.

Data Collection

The measures for this study were collected at two separate appointments. At the first testing appointment, participants were screened to determine if they met the eligibility criteria. Only those meeting the eligibility requirements completed the testing battery. In order to minimize subject burden or fatigue, rest periods were provided every 30-45 minutes at each

testing session and participants were encouraged to request additional breaks if needed during testing.

Data Analysis

In the parent study, all data were de-identified and underwent a thorough quality control process to ensure consistency of scoring, coding and accuracy of data entry. SPSS (version 21.0) was used for data analysis. For this dissertation project, data pertinent to these analyses were abstracted and saved to a new file in SPSS. A copy of the codebook from the parent study was used to interpret how the data were coded and to identify missing data. The file was kept in a password-protected file on a secure server. Only the investigator and her committee chairs had access to these data. In order to address the aims of this study, variables were recoded or new variables were created. Following these procedures, a research assistant double-checked the coding accuracy of the new data file. The data were examined for outliers and the distribution of each continuous variable was examined for skewness and kurtosis using a one-sample Kolmogorov-Smirnov (K-S) test. This informed the use of parametric versus non-parametric methods and whether transformations (e.g. log base 10) were needed to approximate normal distributions. For analyses, demographic variables and the scores of the hearing, cognitive performance and depressive symptoms measures were expressed as mean ± standard deviation (SD) or frequencies and percentages.

Data Analysis of Each Aim

Aim 1. Explore cognitive performance across varying levels of hearing acuity in older adults.

Research question: What is the relationship between hearing acuity and cognitive performance in older adults?

In bivariate analyses, Pearson's product moment correlations were calculated to examine the relationship between the measures of hearing and cognitive performance. The Pearson correlations coefficient (*r*) is an index of the strength of the linear relationship between two variables. To correct the family-wise error rate associated with multiple comparisons, a Bonferroni correction was applied to adjust the 2-sided *p*-value <0.05, and an alpha level of .006 was used define statistical significance in all analyses. In addition, the correlation coefficients were used to estimate effect size. According to Tabachnick & Fidell (2007), effect size is the measure of the strength of the relationship between two variables. Using Cohen's (1992) definition of effect size, the magnitude was qualified as: (a) small (.10); (b) medium (.30) or (c) large (.50).

Aim 2. Explore the impact of depressive symptoms on the relationship between hearing acuity and cognitive performance.

Research question: What is the influence of depressive symptoms on cognitive performance in older adults with varying levels of hearing acuity?

To evaluate the influence of depressive symptoms as a potential mediator on cognitive performance in older adults with varying levels of hearing acuity, analyses were employed according to Baron and Kenny's (1986) model of mediation. However, the regression analyses did not meet the necessary assumptions. Therefore, Spearman correlation coefficients were calculated to examine the strength of the relationships among the variables of interest.

Table 1. *Summary of Hearing and Cognitive Performance Measures*

Measure Name/Abbreviation		Description	Data
Peripheral Hearing			
Standard pure tone average (PTA) right & left ear	R_std_PTA L_std_PTA	Average of pure tone frequencies .50, 1 & 2 kHz for right and left ear	Measured in decibels (dB). Normal hearing PTA = 0 to 25 dB; mild loss PTA = 26 to 45 dB; moderate loss PTA = 46 to 65 dB; severe loss PTA = > 65 dB
High frequency pure tone average (PTA) right & left ear	R_HF_PTA L_HF_PTA	Average of pure tone frequencies 4, 6 & 8 kHz for right and left ear	
Tympanometry	Tymp	Slight pressure delivered to tympanic membrane to assess middle ear function	Categorized as normal = type A; abnormal = type B & C
Words-in-Noise	WIN	Single words delivered in various noisy background environments (Signal-to-babble ratios)	Signal-to-babble thresholds (dB); lower thresholds = poorer performance
Central Auditory Processing			
Time Compressed Speech (TCS)	TCS45 TCS65	Recording of 50 words delivered binaurally at 45% and 65% compression	Percent (%) correct word recognition-two conditions; higher % = better performance
Synthetic Speech Identification with Ipsilateral Competing Message	SSI-ICM	Meaningless sentence and competing meaningful narrative delivered to same ear at same sound level-must identify meaningless sentence from list of 10 sentences	Percent (%) correct combined across ears; score ≥ 80% = normal performance
Dichotic Sentence Identification	DSI	Different meaningless sentences delivered simultaneously to each ear-must identify both sentences from list of 10 sentences	Percent (%) correct sentence identification-both ears; score ≥ 80% = normal performance
Dichotics Digits Test	DDT	Two pairs of numbers are delivered to each ear simultaneously-must identify all numbers	Percent (%) correct identification of 2 or 3 numbers/ear; score ≥ 90% = normal performance
Cognitive performance			
Executive Function Controlled Oral Word Association Test	COWAT	Must verbally produce as many words as possible beginning with letters C, F & L (60 seconds for each letter)	Total number of words produced per letter from all three trials; higher score = better performance
Trail Making Test A and B	Trl_A Trl_B	Must connect a series of 25 semi-randomly arranged inscribed circles in increasing and/or alternating order. Test A: numbers only; Test B: numbers and letters	Total time in seconds for each trial. Lower total time = better performance
Speed of Processing Adaptive Test of Temporal Resolution (within channel & across channel gap detection thresholds)	ATTR_WC ATTR_AC	Two short intervals of sound (one continuous and one containing silent gap) delivered-must identify the interval containing gap	Geometric mean of the detectable gap lengths in milliseconds (ms); higher gap detection thresholds (GDTs) = poorer performance
Pattern Comparison Processing Speed Test	PCPS	Two visual patterns are presented-must indicate if patterns are same or different	Total number of correct answers in 90 seconds; higher score = better performance
Memory Rey Auditory Verbal Learning Test (AVLT)	RAV_I RAV_D	A list of 15 unrelated words are presented verbally, must provide immediate and delayed recall of words (three trials of immediate recall, one trial delayed recall after 30 minutes)	Two scores: total number of words recalled across immediate trials and total for delayed trial; higher score = better performance

Chapter 4
Results

In this chapter, the results are presented. First, the preliminary data analyses will be described. Second, descriptive statistics for the selected variables included in this secondary data analysis will be reported. This will include demographic characteristics as well as a description of participant hearing status, cognitive performance and depressive symptom scores. Then, the specific results for the specific aims will be presented.

Preliminary Analyses

Data were screened for outliers using standardized scores. Standardized scores, or *z* scores, represent the distance a participant lies from the average score on any given variable, and is measured in standard deviations. According to Tabachnick and Fidell (2007), scores on any variable, which are more than 3.29 standard deviations from the mean, are considered outliers, and are in some cases removed from the data. As such, *z* scores were calculated for each of the variables of interest to the study, and were visually assessed for values greater than 3.29, or lower than -3.29. One participant was found to have outlying values for Trail making B. In addition, one participant was found to have outlying values for the Adaptive Test of Temporal Resolution (across channel) and one participant had outlying values for Synthetic Sentence Identification with Ipsilateral Competing Message test. Univariate normality for each continuous variable was examined both with and without the outliers using a one-sample K-S test.

Significance test scores along with visual inspection of the graphical representation of the K-S tests for the variables were evaluated to determine the normality of the data. Outliers were removed. Based on the distribution of the data, the variables were categorized as (a) normal distribution, (b) positive skewness, (c) negative skewness, (d) positive kurtosis or (e) negative kurtosis. Skewness is a lack of symmetry, with the bulk of the scores clustered at one end of the distribution. Kurtosis describes the "peakedness" of the distribution of scores (Tabachnick & Fidell, 2007). Table 2 displays the distribution of data for the variables used in the present study. For all variables with positive and negative skewness, the appropriate transformations were conducted. However, for the GDS, HHI, SSI-ICM and R_std_PTA, several various transformations were attempted and none were able to contribute to a greater degree of normality. Therefore, the data were not transformed (Tabachnick & Fidell, 2007).

Table 2. *Distribution of Data for Variables*

Normal Distribution	Positive Skewness	Negative Skewness
R_HF_PTA	L_std_PTA	TCS45
DDT	R_std_PTA	TCS65
COWAT	L_HF_PTA	SSI_ICM
PCPS	WIN	DSI
ATTR_AC	GDS	RAV_I
RAV_D	ATTR_WC	
Trl_A	HHI	
Trl_B		

R_HF_ PTA = High frequency PTA right ear; DDT = Dichotic digits test; COWAT = Controlled oral word association; PCPS = Pattern comparison processing speed; ATTR_AC = Auditory test of temporal resolution across channel; RAV_D = Rey auditory verbal learning test delayed recall; Trl_A = Trail making A; Trl_B = Trail making B; L_std_PTA = Standard PTA left ear; R_std_ PTA = Standard PTA right ear; L_HF_ PTA = High frequency PTA left ear; WIN = Words-in-noise test; GDS = Geriatric Depression Scale; ATTR_WC = Auditory test of temporal resolution within channel; HHI = Hearing Handicap Inventory; TCS45 = Time compressed speech at 45% compression; TCS65 = Time compressed speech at 65% compression; SSI-ICM = Synthetic sentence identification with ipsilateral competing message; DSI = Dichotic sentence identification; RAV_I = Rey auditory verbal learning test immediate recall.

Descriptive Statistics

Demographic Characteristics

The results of the demographic characteristics for the sample (N = 30) included in this secondary data analysis are presented in Table 3. The age of the participants ranged from 60 to

83 years and all participants completed at least 12 years of education. The majority of the sample were female and married. There was no racial diversity as all participants were Caucasian/White. In regards to health status, most described their health as either "excellent" or "very good," and only a few reported any history of neurologic co-morbidity (e.g. stroke, Parkinson's disease or multiple sclerosis).

Table 3. *Descriptive Characteristics for Participants*

Variable	*M*	*SD*	*n*	%
Age	67.70	5.88		
Education (years)	15.10	2.45		
Sex				
Female			19	63.3
Male			11	36.7
Race				
White			30	100.0
Marital status				
Divorced			4	13.3
Married			20	66.7
Single			4	13.3
Widowed			2	6.7
General health status				
Excellent			4	13.3
Very good			14	46.7
Good			9	30.0
Fair			3	10.0
Neurologic co-morbidity				
No			25	83.3
Yes			5	16.7

Hearing Status

Peripheral hearing. The results of the pure tone air threshold testing for the participants

are presented in Figure 2. These scores are consistent with the typical audiogram pattern of high-frequency hearing loss frequently observed in the older adult.

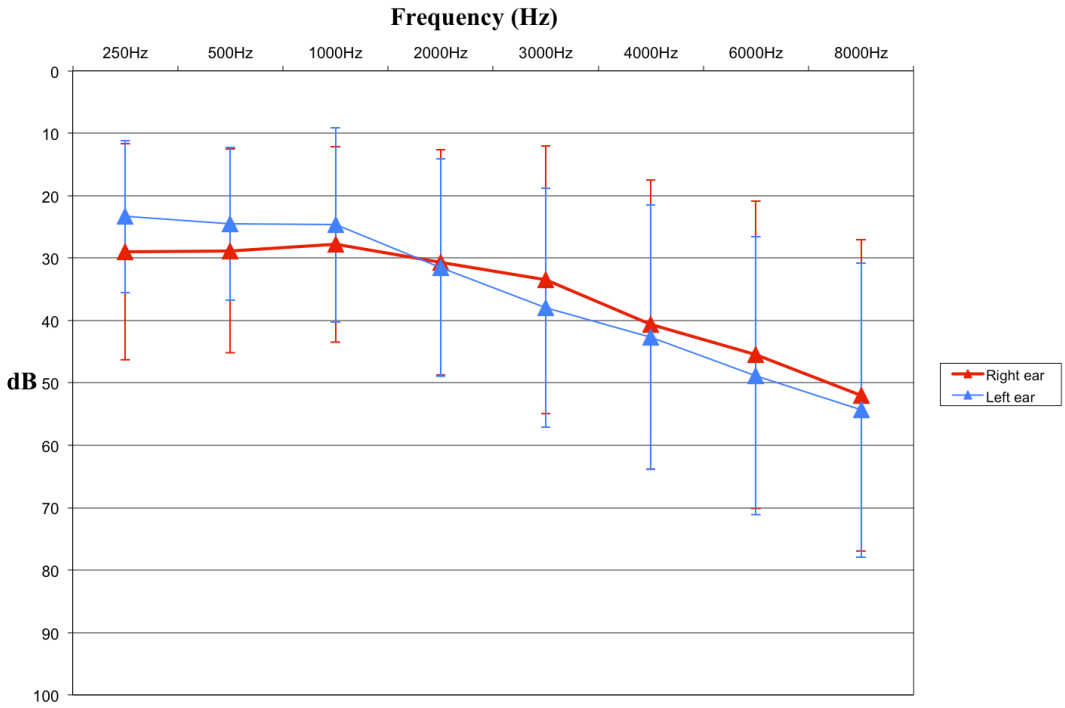

Figure 2. *Mean pure-tone thresholds for participants.*

The mean pure-tone average scores are presented in Table 4. When comparing ears, there was minimal difference in mean standard and high frequency PTA scores for the left and right ear, suggesting overall symmetry of hearing thresholds. It should be noted that during individual audiometric testing, no conductive or mixed hearing loss was identified and all participants had normal tympanometry results. Therefore, any hearing loss that was detected during peripheral

Table 4. *Mean Pure-Tone Average (PTA) Scores for Participants*

Variable	*n*	Minimum	Maximum	*M*	*SD*
L_std_PTA	30	10.00	66.67	27.11	13.40
R_std_PTA	30	11.67	73.33	29.00	15.68
L_HF_PTA	30	11.67	96.57	48.39	20.57
R_HF_PTA	30	15.00	100.00	45.83	22.56
WIN	30	2.00	18.80	7.10	4.21

Note. Scores for standard and high frequency PTA are reported in decibels (dB). Scores for Words-in-Noise are reported as signal-to-babble thresholds (dB). L_std_PTA = Left ear standard pure tone average; R_std_PTA = Right ear standard pure tone average; L_HF_PTA = Left ear high frequency pure tone average; R_HF_PTA = Right ear high frequency pure tone average and WIN = Words-in-noise test.

hearing testing was classified as sensorineural hearing loss. Only four (13.3%) of the participants wore hearing aids. Figure 3 shows the frequencies for the individual results of the standard and high frequency PTA categorized by level of hearing loss.

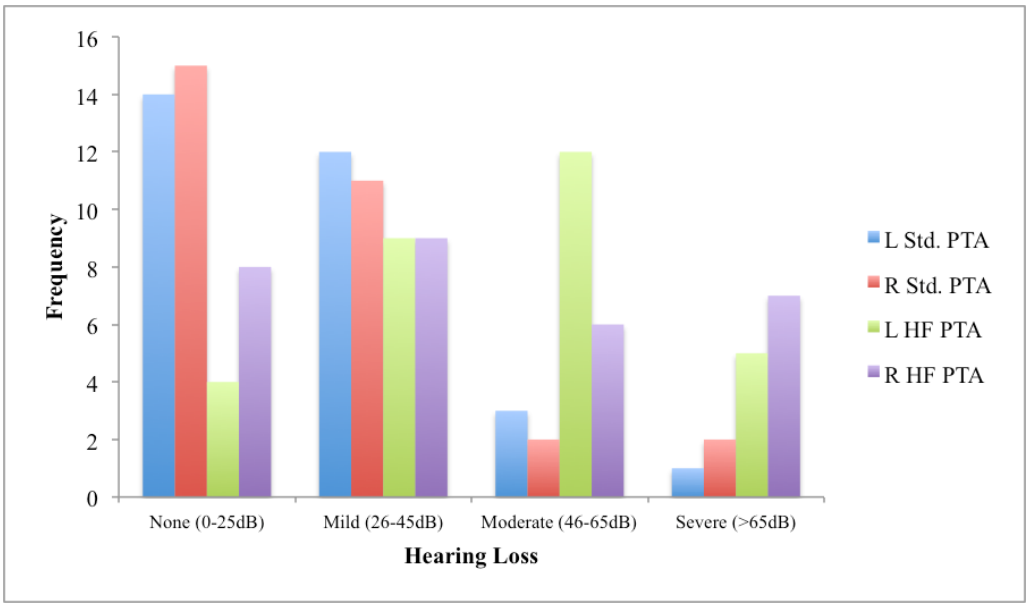

Figure 3. *Frequencies for individual level of hearing loss.*

For the standard PTA, the majority (86.7%) of the participants fell into the category of either no hearing loss or mild hearing loss for both the left and right ear, indicating the sample was not evenly distributed among all categories of hearing loss. The high frequency PTA scores revealed that just over half of participants (56.7%) fell into the category of moderate or severe hearing loss in the left ear, whereas for the right ear, more than half (56.7%) were categorized with either no or mild hearing loss.

Central auditory processing. The results of the central auditory tests are presented in Table 5. For the SSI-ICM and DDT, the test assessed hearing status in the left and right ear and then scores were combined scores for a total score. There was a wide range of scores on all tests, indicating significant variability in participant performance.

Table 5. *Mean Central Auditory Processing Test scores for Participants*

Measure	*n*	Minimum	Maximum	*M*	*SD*
TCS45	30	30	100	89.63	17.83
TCS65	30	18	90	65.93	20.16
SSI-ICM	29	45	100	87.59	13.93
DSI	30	0	100	73.13	24.57
DDT	30	40	100	79.27	16.12

Note. Scores are reported as percent (%) correct responses. TCS45 = Time compressed speech at 45% compression; TCS65 = Time compressed speech at 65% compression; SSI-ICM = Synthetic speech identification with ipsilateral competing message; DSI = Dichotic sentence identification; DDT = Dichotic digits test.

Hearing Handicap Inventory. Participant scores for the HHI ranged from 0 to 40, with a mean and standard deviation of (M =7.93, SD = 10.25). In addition, individual scores were categorized by level of perceived handicap as (a) no handicap (score 0 to 9); (b) mild to moderate handicap (score 10 to 22); and significant handicap (score 23 to 40), revealed a majority of the sample fell into the category of no perceived handicap (63.3%).

Cognitive Performance

Table 6 summarizes the results of the cognitive performance testing for the participants. The wide range of scores among the measures implies the sample was heterogeneous in their level of cognitive performance. This is confirmed by the observed variability of the standard deviations associated with the scores.

Depressive Symptoms

Participant scores for the GDS-15 ranged from 0 to 11, with a mean and standard deviation of (M = 1.43, SD = 2.30). These results reveal a low level of self-perceived depressive symptoms for the sample. The individual scores were categorized by level of depressive symptoms and are displayed in Figure 4. These results confirm that the majority of participants fell into the category of no depressive symptoms (90%).

Table 6. *Mean Cognitive Performance Scores for Participants*

Domain/Measure	*n*	Minimum	Maximum	*M*	*SD*
Processing Speed					
PCPS	30	22.00	64.00	42.33	9.63
ATTR_AC	28	14.61	80.79	45.61	19.41
ATTR_WC	30	1.57	20.38	7.46	5.01
Executive Function					
Trl_A	28	21.22	58.41	37.39	9.31
Trl_B	27	46.85	168.91	88.77	33.78
COWAT	30	20.00	77.00	37.83	12.60
Memory					
RAV_I	30	6.00	29.00	20.90	5.61
RAV_D	30	0.00	11.00	5.40	2.91

Note. Scores are reported as total score for PCPS, COWAT, RAV_I and RAV_D; time in seconds for Trl_A and Trl_B and the geometric mean of the detectible gap lengths in milliseconds (ms) for ATTR_AC and ATTR_WC. PCPS = Pattern comparison processing speed; ATTR_AC = Auditory test of temporal resolution (across-channel); ATTR_WC = Auditory test of temporal resolution (within channel); Trl_A = Trail making A test; Trl_B = Trail making B test; COWAT = Controlled oral word association test; RAV_I = Rey auditory verbal learning test immediate recall; RAV_D = Rey auditory verbal learning test delayed recall.

Analyses for the Specific Study Aims

Aim 1

The primary aim of this study was to explore cognitive performance across varying levels hearing acuity in older adults. To examine the bivariate relationship between these continuous variables, Pearson's correlations (*r*) were calculated for all measures of hearing acuity and cognitive performance. Since each variable was used eight times, a Bonferroni correction to the alpha level was used; thus a new alpha level of .006 (.05 / 8) was used to determine statistical significance. The correlation coefficients were interpreted to estimate the strength of the association between these variables using Cohen's definition of effect size as (a) small (.10); (b) medium (.30) or (c) large (.50) (Cohen, 1992). A positive correlation indicates that as the score on one variable tends to increase, the score on the other variable also increases or as when the score on one variable decreases, the score on the other variable also decreases. Inversely, a negative correlation signifies that as the score on one variable tends to increase, the score on the other variable tends to decrease.

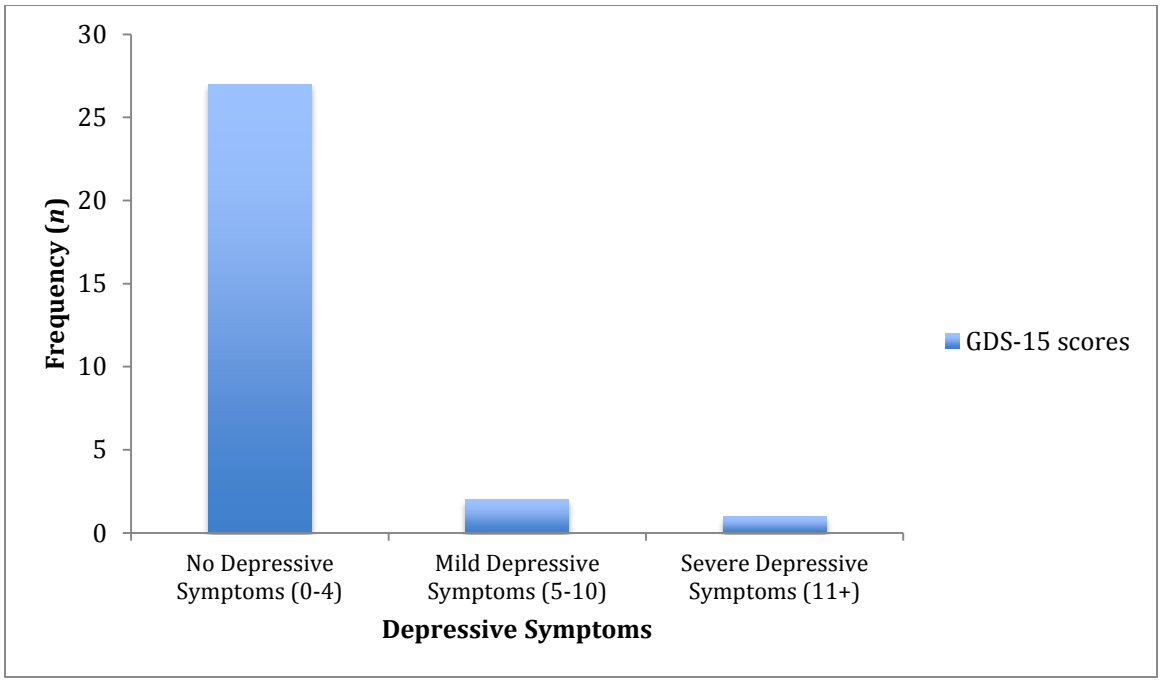

Figure 4. *Frequencies for individual level of depressive symptoms.*

Trl_B was significantly negatively correlated with DSI r = -.565, n = 27, $p \leq .006$, suggesting as scores on DSI decreased, scores on Trl_B increased. This result estimates a large effect size for the relationship between Trl_B and DSI.

Furthermore, a significant positive correlation was observed between ATTR_WC and R_ std_PTA r = .548, n = 30, $p \leq .006$, indicating as scores on R_std_PTA increased, the score on ATTR_WC also increased. In addition, ATTR_WC was significantly negatively correlated with DDT r = -.531, n = 30, $p \leq .006$, implying as scores on DDT decreased, scores on ATTR_WC increased. The strength of these correlations estimate large observed effect sizes for the relationship between these variables. Table 7 shows the full Pearson correlation matrix. A separate Pearson correlation was calculated to explore the relationship between HHI and the measures of cognitive performance. No significant correlations were found and, therefore, the results were not included in the full correlation matrix. While the correlations coefficients for

several of the hearing and cognitive performance measures were not statistically significant at the adjusted alpha level ($p \leq .006$), a medium effect size was observed. Table 8 presents the observed effect sizes (r) for these variables. The results suggest a moderate association may exist between certain these measures of hearing and cognition.

Aim 2

The secondary aim of this study was to explore the impact of depressive symptoms on the relationship between hearing acuity and cognitive performance. As stated previously, the majority of the participants (n = 27) reported no depressive symptoms. Originally, a mediation analysis was proposed to utilize linear regression analysis to assess the mediating effect of depression on the relationship between hearing loss and cognitive performance. Primary steps of the analysis include a determination of the relationship between the independent and dependent variables, independent and mediating variables, and mediating and dependent variables (Baron & Kenny, 1986). However, the resulting regression analyses did not meet the necessary assumptions and a non-parametric correlational analysis was conducted in place of the regression. Spearman correlations were chosen to examine the relationships of interest, as these analyses may be used to assess bivariate relationships but do not rely on the same restrictive assumptions as a regression analysis. The results revealed no significant correlations between the measure of (depressive symptoms) and the measures for the independent variable (hearing status) or the dependent variable (cognitive performance).

Table 7. *Pearson Correlations for Hearing and Cognitive Performance Measures*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 L_std_PTA	1.00	.835**	.808**	.777**	.786**	-.656**	.355	-.326	.643**	.630**	.116	.166	.171	-.100	.171	.485	.137	.238
2 R_std_PTA		1.00	.576**	.751**	.764**	-.620**	.431	-.471	.668**	.646**	.062	.041	.027	-.175	.164	.548*	.076	.159
3 L_HF_PTA			1.00	.843**	.745**	-.540**	.347	-.336	.736**	.721**	-.193	.156	.271	-.085	.262	.419	.341	.039
4 R_HF_PTA				1.00	.814**	-.543*	.451	-.517*	.697**	.716**	-.173	.140	.163	-.240	.332	.459	.253	.040
5 WIN					1.00	-.669**	.444	-.533*	.852**	.795**	-.031	.111	.080	-.004	.300	.454	.305	.050
6 SSI-ICM						1.00	-.575**	.458*	-.589**	-.669**	.013	-.343	-.326	-.177	-.194	-.339	-.214	.045
7 DSI							1.00	-.764**	.429	.412	-.172	-.409	-.565*	.361	.130	-.313	.282	-.339
8 DDT								1.00	-.454	-.406	.025	-.438	-.452	.384	-.191	-.531*	.005	.136
9 TCS45									1.00	.841**	-.173	.136	-.317	-.033	.252	-.352	.367	-.085
10 TCS65										1.00	-.213	.078	.153	.019	.318	-.403	.363	-.146
11 COWAT											1.00	-.055	-.092	-.186	.118	.139	-.573**	.449
12 Trl_A												1.00	.722**	-.374	-.292	.051	.138	-.098
13 Trl_B													1.00	-.477	-.235	-.127	.112	-.140
14 PCPS														1.00	-.132	-.115	.042	.227
15 ATTR_AC															1.00	.336	.050	-.161
16 ATTR_WC																1.00	-.133	.116
17 RAV_I																	1.00	-.612**
18 RAV_D																		1.00

Note. *$p \leq .006$ (Bonferroni correction); **$p \leq .001$. L_std_PTA = Standard PTA left ear; R_std_ PTA = Standard PTA right ear; L_HF_ PTA = High frequency PTA left ear; R_HF_ PTA = High frequency PTA right ear; WIN = Words-in-noise test; SSI-ICM = Synthetic sentence identification with ipsilateral competing message; DSI = Dichotic sentence identification; DDT = Dichotic digits test; TCS45 = Time compressed speech at 45% compression; TCS65 = Time compressed speech at 65% compression; COWAT = Controlled oral word association; Trl_A = Trail making A; Trl_B = Trail making B; PCPS = Pattern comparison processing speed;; ATTR_AC = Auditory test of temporal resolution across channel; ATTR_WC = Auditory test of temporal resolution within channel; RAV_I = Rey auditory verbal learning test immediate recall; RAV_D = Rey auditory verbal learning test delayed recall.

Table 8. *Medium Effect Sizes Observed/Correlation Coefficients that were not Statistically Significant at the p ≤ .006 Level*

	Cognitive Performance						
Hearing	Trl_A	Trl_B	PCPS	ATTR_AC	ATTR_WC	RAV_I	RAV_D
L_std_PTA					*r* = .485 (*n* = 30)		
L_HF_PTA					*r* = .419 (*n* = 30)	*r* = .341 (*n* = 30)	
R_HF_PTA				*r* = .332 (*n* = 28)	*r* = .459 (*n* = 30)		
WIN				r = .300 (*n* = 28)	*r* = .454 (*n* = 30)	*r* = .305 (*n* = 30)	
SSI-ICM	*r* = -.343 (*n* = 27)	*r* = -.326 (*n* = 26)			*r* = -.339 (*n* = 29)		
DSI	*r* = -.409 (*n* = 28)		*r* = -.361 (*n* = 30)		*r* = -.313 (*n* = 30)		*r* = -.339 (*n* = 30)
DDT	*r* = -.438 (*n* = 28)	*r* = -.452 (*n* = 27)	*r* = -.384 (*n* = 30)				
TCS45		*r* = -.317 (*n* = 27)			*r* = -.352 (*n* = 30)	*r* = .367 (*n* = 30)	
TCS65				*r* = .318 (*n* = 28)	*r* = -.403 (*n* = 30)	*r* = .363 (*n* = 30)	

L_std_PTA = Standard PTA left ear; L_HF_PTA = High frequency PTA left ear; R_HF_PTA = High frequency PTA right ear; WIN = Words-in-noise test; SSI-ICM = Synthetic sentence identification with ipsilateral competing message; DSI = Dichotic sentence identification; DDT = Dichotic digits test; TCS45 = Time compressed speech at 45% compression; TCS65 = Time compressed speech at 65% compression; Trl_A = Trail making A; Trl_B = Trail making B; PCPS = Pattern comparison processing speed;; ATTR_AC = Auditory test of temporal resolution across channel average; ATTR_WC = Auditory test of temporal resolution within channel average; RAV_I = Rey auditory verbal learning test immediate recall; RAV_D = Rey auditory verbal learning test delayed recall.

Chapter 5
Discussion

The purpose of this study was to explore the relationship between hearing ability and cognitive performance as well as to examine the influence of depressive symptoms on cognitive performance in older adults with varying levels of hearing acuity. The hypothesized conceptual framework proposed a direct relationship between hearing status and cognitive performance, and that depressive symptoms might act as a mediator, influencing cognitive performance. An important aspect of this study was that it is one of only a few studies providing evidence for the relationship between hearing acuity and cognitive performance in older adults utilizing comprehensive measures of both hearing (peripheral and central auditory processing) and cognitive performance (specific for executive function, memory and processing speed). Moreover, this innovative study included a self-report assessment for depressive symptoms. To the present author's knowledge, this is one of the first studies that attempted to explore the influence of depressive symptoms on the relationship between hearing loss and cognitive performance in the older adult.

The Relationship between Hearing Status and Cognitive Performance

The primary aim was to explore the relationship between hearing status and cognitive performance in the older adults. The results of the current study revealed an inverse linear relationship between central auditory processing and executive function indicating that as participant performance on the Dichotic Sentence Identification test worsened, the duration of

time for completion of the Trail Making B test by participants increased. A positive linear relationship was shown between speed of processing and peripheral hearing, signifying that as pure-tone thresholds in right ear increased, the within channel gap detection thresholds of the Adaptive Test of Temporal Resolution (ATTR) also increased. In addition, an inverse linear relationship was observed between central auditory processing and speed of processing, indicating that as performance on the Dichotic Digits test worsened, participant performance was poorer on the Adaptive Test of Temporal Resolution (within channel thresholds). While Pearson correlations (*r*) were not statistically significant, moderate effect sizes were detected between several of the other measures of hearing (peripheral and central auditory processing) and measures for the various domains of cognitive performance. These results support the aspect of the hypothesized conceptual model of this study that a direct relationship exists between hearing and cognitive performance in older adults.

The findings in the current study are in concordance with previous cross-sectional studies of older adults that have documented a significant relationship between measures of central auditory processing and measures of executive function (Gates et al., 2010; Hommet et al., 2010), and speed of processing (Hallgren, Larsby, Lyxell, & Arlinger, 2001). Central auditory processing deficits have also been observed in older adults with impaired cognitive performance ranging from mild memory impairment to Alzheimer's disease (Gates, Anderson, Feeney, McCurry, & Larson, 2008; Idrizbegovic et al., 2011). Interestingly, the majority of participants in the present study had normal or mild peripheral hearing loss; minimal self-perceived hearing handicap and only a minority of participants (13.3%) wore hearing aids. However, the mean scores for all central auditory processing measures (except SSI-ICM) were below the normal score proposed for adults. These results lend support to other studies that have observed central

auditory processing deficits in older adults with similar levels peripheral hearing loss (Gates, Feeney, & Mills, 2008; Sanchez, Nunes, Barros, Gananca, & Caovilla, 2008).

Several epidemiological studies have reported a significant relationship between peripheral hearing and global measures of cognition (Gallacher et al., 2012; Lin, Ferrucci, et al., 2011; Lin et al., 2013), and measures of speed of processing (Lin, 2011; Lin, Ferrucci, et al., 2011; Lin et al., 2013). In a recent study, Bush, Lister, Lin, Betz and Edwards (2015) documented a significant association between peripheral hearing and a measure of global cognition, as well as multiple measures of cognitive performance specific for executive function, memory and speed of processing in a large cohort of older adults. An important limitation of these previous studies is that they only used a single measure of peripheral hearing, either calculated as a three frequency (0.5, 1 and 2 kHz) PTA (Bush, Lister, Lin, Betz, & Edwards, 2015), or a four frequency (0.5, 1, 2 and 4 kHz) PTA (Gallacher et al., 2012; Lin, Ferrucci, et al., 2011; Lin et al., 2013) in the better hearing ear. Further, these studies did not include measures for the higher frequencies, often decreased in the older adult. Therefore, the degree of hearing loss may have been underestimated. While not statistically significant in the present study, moderate effect sizes were observed between the left high frequency PTA and measures specific for speed of processing and memory; and the right high frequency PTA and speed of processing. These findings suggest that future studies, which examine the relationship between peripheral hearing and cognitive performance, should use hearing measures inclusive of high frequency pure tones.

In the current study, a statistically significant relationship was revealed between peripheral hearing and speed of processing. However, this is an unexpected finding as previous studies have documented that reduced speed of processing (indexed as within-channel gap

detection thresholds of the ATTR) is not directly associated with hearing acuity (Grose, Hall, & Buss, 2001; J. Lister, Besing, & Koehnke, 2002; J. J. Lister, Koehnke, & Besing, 2000). One possible explanation for this unexpected result in this sample may be the effect of age. Lister, Roberts and Lister (2011) compared gap detection thresholds (GDTs) in older adults, young adults and children. They found poorer GDTs in the older adults compared to the young adults and children, suggesting gap detection capabilities change with age. Other studies have also demonstrated that poorer gap detection threshold detection is more associated with age than hearing acuity (Grose et al., 2001; J. Lister et al., 2002). In addition, a significant association was observed between the words-in noise test (a measure of peripheral hearing) and a verbal learning test that assessed memory performance in observed older adults with moderate hearing loss (Choi, Shim, Lee, Yoon, & Joo, 2011; Verhaegen, Collette, & Majerus, 2013). Though not statistically significant, the current study detected a moderate effects size between the words-in-noise test and the Rey Auditory Verbal Learning test (immediate recall score), a measure specific for memory. Further investigation is needed to explicate the relationship between these variables.

It should be noted that a small number of cross-sectional (Gates et al., 1996; Idrizbegovic et al., 2011) and longitudinal (Gates, Beiser, Rees, D'Agostino, & Wolf, 2002) studies have failed to observe a significant relationship between peripheral hearing and cognitive performance. Possible explanations for the results of these studies include the use of a single measure of hearing that did not include high frequency pure tones (Gates et al., 2002; Gates et al., 1996); a low prevalence of hearing loss among participants (Idrizbegovic et al., 2011); and the use of a cross-sectional design (Gates et al., 1996; Idrizbegovic et al., 2011).

The findings of a previous study by Lin et al. (2011) demonstrated older adults with peripheral hearing loss were at increased risk for incident dementia (Lin, Metter, et al., 2011).

The results of other longitudinal studies have suggested that central auditory dysfunction may precede the onset of the clinical manifestations Alzheimer's disease (Gates, Anderson, McCurry, Feeney, & Larson, 2011; Gates et al., 2002). While the prevalence of age-related hearing loss is high and there are detrimental negative consequences associated with this condition, it is under diagnosed and under treated in this vulnerable population (Agrawal, Platz, & Niparko, 2008; Cohen, Labadie, & Haynes, 2005; Gopinath et al., 2012). Therefore, early diagnosis and treatment is vital to reduce the negative impact of hearing loss on cognitive performance, promoting the maintenance of functional independence in the older adult.

Gates et al. (2010) assert central auditory processing tests may be more sensitive to preclinical cognitive performance deficits than global measures of cognition in older adults. However, central auditory processing testing is rarely performed in older adults during routine hearing assessment. Since comprehensive hearing and cognition measures were used in this study, a significant relationship between hearing and cognition was revealed. These findings offer supportive evidence for the addition of central auditory processing tests to routine hearing assessment protocols. Moreover, central auditory processing measures should be included in future research that explores the relationship between hearing and cognitive performance in the older adult.

As stated previously, the mechanisms underlying the relationship between hearing and cognitive performance are complex. Specific hypotheses that exist within the literature that may be used to explain the findings of the present study include: (1) the *common cause hypothesis*, that asserts widespread neural degeneration is responsible for both diminished hearing acuity and cognition (Lindenberger & Baltes, 1994) and (2) the *sensory deprivation hypothesis*, that claims reduced sensory input (such as hearing loss) leads to a decline in cognitive performance

(Arlinger, Lunner, Lyxell, & Pichora-Fuller, 2009; Lindenberger & Baltes, 1994). Humes et al. (2012) conducted a comprehensive review of 132 studies that examined central auditory processing in older adults and concluded, "central auditory declines in aging were most often intertwined with age-related declines in peripheral hearing, cognition or both" (p.636). It is unlikely that the over-diagnosis theory (previously discussed in Chapter 2), explains the result of the current study, as individuals with severe hearing loss or dementia were excluded from participation.

The Influence of Depressive Symptoms on the Relationship between Hearing Acuity and Cognitive Performance

The second aim was to explore the impact of depressive symptoms on cognitive performance in older adults with varying levels of hearing acuity. In this secondary analysis, depressive symptoms, as measured by the General Depression Scale (GDS), was not significantly correlated to any measure of hearing loss. Furthermore, there were no significant correlations between depressive symptoms and the cognitive performance measures. These results do not support the hypothesized conceptual model proposed in this study.

In the older adult, depressive symptoms are two to three times more prevalent than major depression (Meeks, Vahia, Lavretsky, Kulkarni, & Jeste, 2011). Previous researchers have observed an association between depressive symptoms and hearing loss in older adults (Boi et al., 2012; Lee, Tong, Yuen, Tang, & Vanhasselt, 2010; Li et al., 2014; Saito et al., 2010). Moreover, an association between depressive symptoms and cognitive performance has also been previously reported (Jungwirth et al., 2011; Spira, Rebok, Stone, Kramer, & Yaffe, 2012). Considering the findings of previous studies and the prevalence of depressive symptoms in older adults, the absence of a significant relationship between these variables in the present study is an

unexpected finding. These results may be due to the small sample size of this study and the low prevalence of depressive symptoms in this population of older adults.

Upon review of previous studies that examined the relationship between hearing loss and depressive symptoms in older adults, it was observed that overall depressive symptoms scores were low in the samples of several studies. For example, Acar, Yurekli, Babademez, Karabulut and Karasen (2010) used the GDS to evaluate depressive symptoms before and after hearing aid fitting in a sample (N = 34) of older adults. Interestingly, the mean (standard deviation) GDS score at baseline was 6.82 (3.95) and decreased to 4.97 (3.46) 3 months following hearing aid fitting. In another trial, the mean GDS score prior to hearing aid fitting was 3.1 (2.81) and then reduced to 2.6 (2.79) four months after hearing aid fitting (Mulrow et al., 1990). Similarly, Metselaar et al (2009) reported low depressive symptom scores on the GDS in a group of older adults with hearing loss. The possible score range for the GDS is 0 to 15 points. Scores are categorized as (a) no depressive symptoms (0 to 4), (b) mild depressive symptoms (5 to 10) and severe depressive symptoms (11 to 15) (Burke, Roccaforte, & Wengel, 1991). The low depressive symptom scores reported in these studies, along with the results of current analysis, suggest the GDS may not be sensitive enough to detect depressive symptoms in older adults with hearing loss and should be further investigated.

Limitations

There are several limitations to the present study. This secondary analysis was planned after data collection had taken place. The cross-sectional design of the parent study restricted the evaluation of hearing status, cognitive performance and depressive symptoms to a single point in time. This limits causality. Due to the small sample size of this study, sample variability was increased and the statistical power was reduced. Confounding variables, such as age, education

and gender were not controlled, increasing the risk of a spurious relationship between hearing loss and cognitive performance. In addition, there was no ethnic diversity in this sample of older adults. While the homogeneity of the sample may strengthen the internal validity, generalizability of these results to younger adults and other racial/ethnic groups is limited.

Another limitation is the sampling method. The parent study used a volunteer, or convenience method of sampling. Consequently, selection bias must be considered. Last, the low prevalence of depressive symptoms and hearing loss in the sample limited the exploration of depressive symptoms as potential mediator on cognitive performance. In order to explore the relationship between variables as proposed in this study, a larger sample of older adults with varying levels of hearing loss, (normal, mild, moderate and severe) and a higher prevalence of depressive symptoms (none, mild and severe) is needed.

Conclusion

Hearing loss and cognitive impairment are common conditions associated with senescence. Previous research has suggested a there is a strong association between these conditions, with adverse effects on the older adult's daily functioning, social interaction and quality of life. In addition, hearing loss and impaired cognition are both related to depression and both are major contributors for institutionalization of the older adult. Hence, exploring the relationship between these pervasive conditions is vital. The current study sought to explore the relationship between hearing loss and depression and the influence of depressive symptoms in a small group of older adults. The results showed significant relationships between measures of central auditory processing and cognitive performance specific for the domains of executive function and speed of processing. Furthermore, a significant relationship was revealed between a

measure of peripheral hearing and speed of processing. Due to the low prevalence of depressive symptoms in this sample, no significant relationships were observed between hearing loss, cognitive performance or depressive symptoms. While not statistically significant, the strength of the relationships between several measures of hearing and cognitive performance suggest there are moderate effects and requires further investigation.

Recommendations for Future Research

In order to expand the existing evidence and the findings of this exploratory study, longitudinal studies including larger samples of older adults with greater ethnic diversity are needed. Longitudinal studies can assess changes in both groups and individuals. Future studies should be designed to include sensitive measures of peripheral hearing (including high frequency pure tones), central auditory processing and measures of cognitive performance specific for the various domains. The addition of biologic measures may offer additional insight into the mechanisms underlying the relationship between these conditions. Stratified sampling methods should be employed to recruit participants with normal, moderate and severe hearing loss. Eligibility criteria should include the requirement that participants have a higher prevalence of depressive symptoms or a confirmed diagnosis of depression. Furthermore, the aims of future studies should examine the efficacy of hearing rehabilitation programs that include cognitive training exercises.

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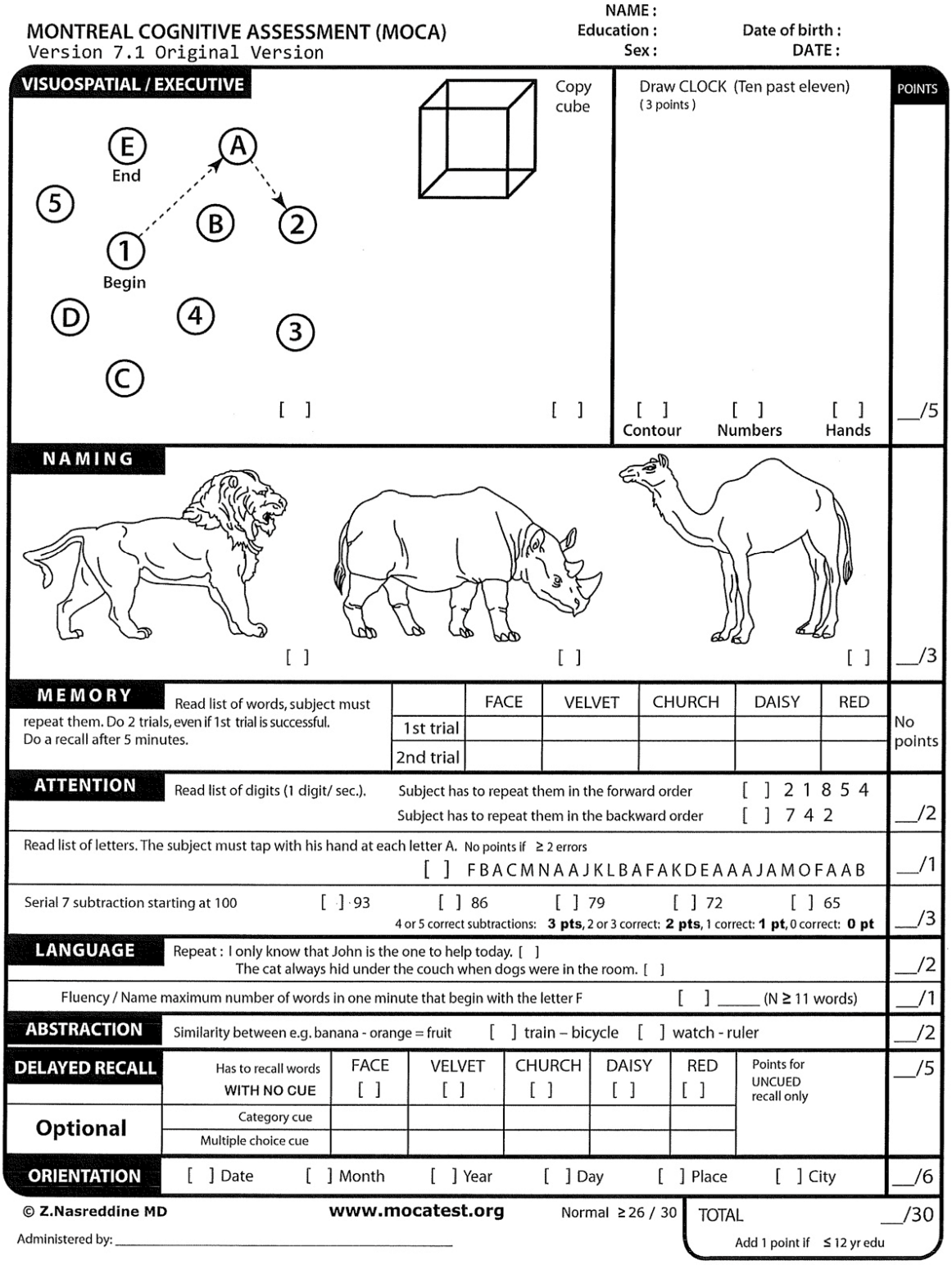
Appendicies

Appendix A: Montreal Cognitive Assessment



MONTREAL COGNITIVE ASSESSMENT (MOCA)
Version 7.1 Original Version

NAME :
Education :
Sex :
Date of birth :
DATE :

VISUOSPATIAL / EXECUTIVE — POINTS

Copy cube

[ ] [ ]

Draw CLOCK (Ten past eleven) (3 points)

[ ] Contour [ ] Numbers [ ] Hands

__/5

NAMING

[ ] [ ] [ ]

__/3

MEMORY Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION Read list of digits (1 digit/ sec.).

Subject has to repeat them in the forward order [ ] 2 1 8 5 4

Subject has to repeat them in the backward order [ ] 7 4 2

__/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors

[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B

__/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65

4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt**

__/3

LANGUAGE Repeat : I only know that John is the one to help today. [ ]

The cat always hid under the couch when dogs were in the room. [ ]

__/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] _____ (N ≥ 11 words)

__/1

ABSTRACTION Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler

__/2

DELAYED RECALL

	Has to recall words WITH NO CUE	FACE [ ]	VELVET [ ]	CHURCH [ ]	DAISY [ ]	RED [ ]	Points for UNCUED recall only
Optional	Category cue						
	Multiple choice cue						

__/5

ORIENTATION [ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City

__/6

© Z.Nasreddine MD www.mocatest.org Normal ≥ 26 / 30

TOTAL __/30

Add 1 point if ≤ 12 yr edu

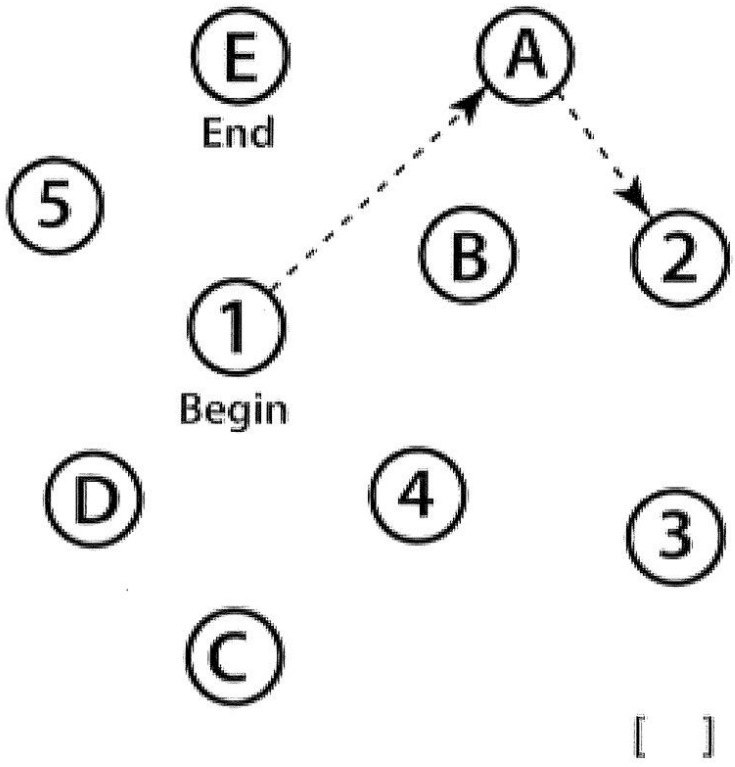
Administered by: _____

Baseline_____ Post Test_____ Subject_____

Date_____

MoCA Trail Making Test

Draw a line going from a number to a letter in ascending order. Begin from 1 – A – 2 – B etc. and end at E.

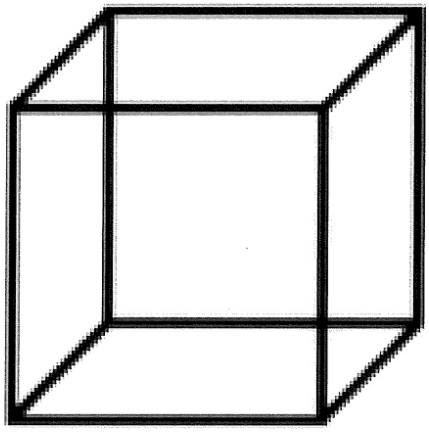


Baseline_____ Post Test_____ Subject_____

Date_____

MoCA Copy the Cube

Copy this drawing, as accurately as you can, in the space below.



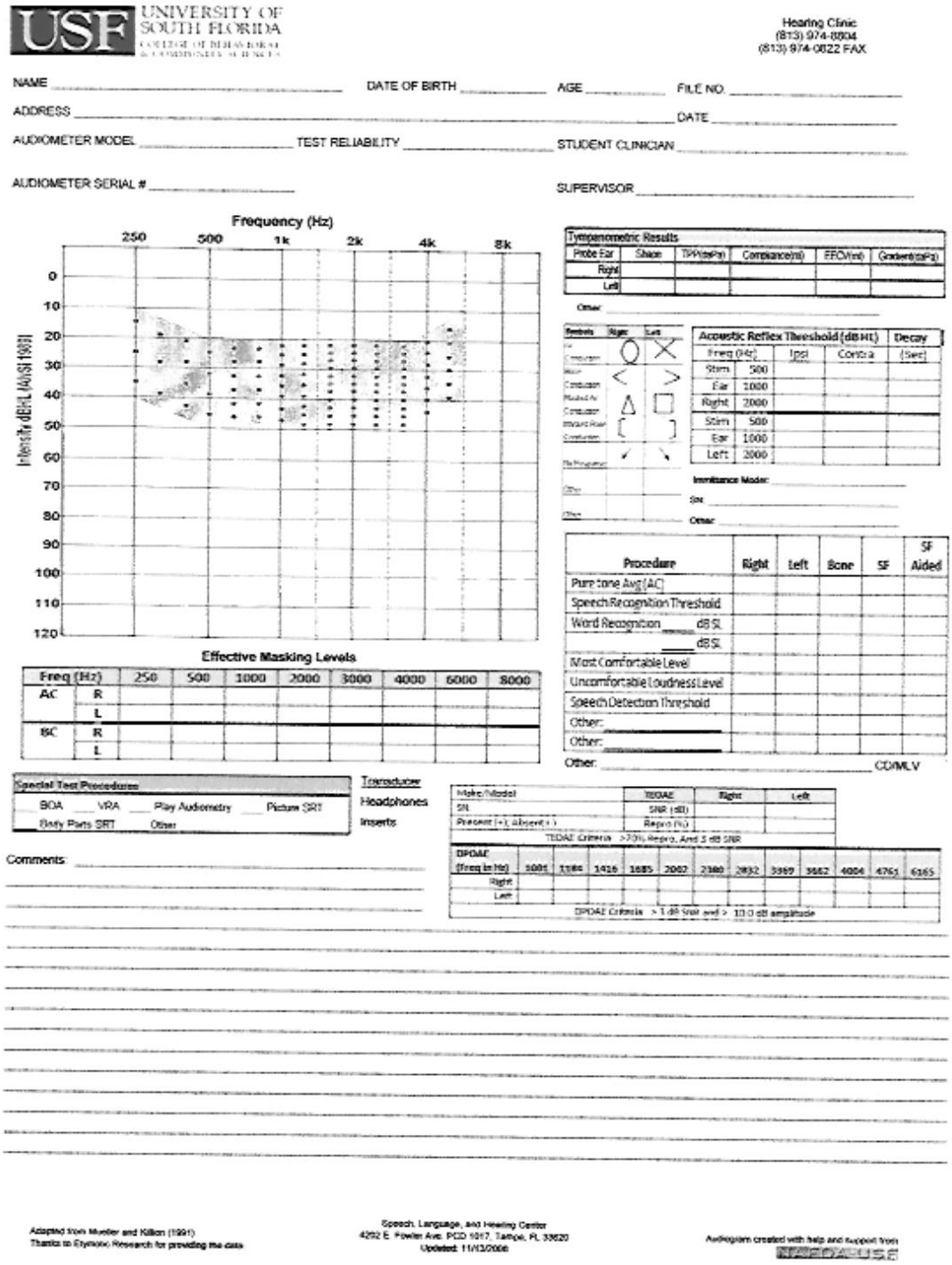
Baseline_____ Post Test_____ Subject_____

Date_____

MoCA Draw a Clock

Draw a Clock. Put in all of the numbers and set the time to 10 after 11.

Appendix B: Peripheral Hearing and Central Auditory Processing Instruments



USF UNIVERSITY OF SOUTH FLORIDA
COLLEGE OF BEHAVIORAL & COMMUNITY SCIENCES

Hearing Clinic
(813) 974-6804
(813) 974-0822 FAX

NAME _____ DATE OF BIRTH _____ AGE _____ FILE NO. _____

ADDRESS _____ DATE _____

AUDIOMETER MODEL _____ TEST RELIABILITY _____ STUDENT CLINICIAN _____

AUDIOMETER SERIAL # _____ SUPERVISOR _____

Frequency (Hz)
250 500 1k 2k 4k 8k
0 10 20 30 40 50 60 70 80 90 100 110 120
Intensity dB re: ANSI 1969

Tympanometric Results

Probe Ear	Shape	TPP(daPa)	Compliance(ml)	ERCV(ml)	Gradient(daPa)
Right					
Left					

Other: _____

Reflexes: Right Left

Acoustic Reflex Threshold (dB HL) / Decay

	Freq (Hz)	Ipsi	Contra	(Sec)
Stim	500			
Ear	1000			
Right	2000			
Stim	500			
Ear	1000			
Left	2000			

Immittance Model: _____
SN: _____
Other: _____

Effective Masking Levels

Freq (Hz)		250	500	1000	2000	3000	4000	6000	8000
AC	R								
	L								
BC	R								
	L								

Procedure	Right	Left	Bone	SF	SF Aided
Pure tone Avg (AC)					
Speech Recognition Threshold					
Word Recognition ____ dB SL					
____ dB SL					
Most Comfortable Level					
Uncomfortable Loudness Level					
Speech Detection Threshold					
Other: _____					
Other: _____					

Other: _____ CD/MLV

Special Test Procedures
BOA ___ VRA ___ Play Audiometry ___ Picture SRT
___ Body Parts SRT ___ Other

Transducer
Headphones
Inserts

Make/Model		TEOAE	Right	Left
SN		SNR (dB)		
Present (+) Absent (-)		Repro (%)		

TEOAE Criteria >70% Repro. And 3 dB SNR

DPOAE (Freq in Hz)	1001	1184	1416	1685	2002	2380	2832	3369	3662	4004	4761	6165
Right												
Left												

DPOAE Criteria > 1 dB SNR and > 10.0 dB amplitude

Comments: _____

Adapted from Mueller and Killion (1991)
Thanks to Etymotic Research for providing the data

Speech, Language, and Hearing Center
4202 E. Fowler Ave. PCD 1017, Tampa, FL 33620
Updated: 11/13/2006

Audiogram created with help and support from HEARCOM-USF

Monday, February 03, 2014

WIN Protocol

Background Information:

- 35 NU No. 6 monosyllabic words.
- 5 words per signal-to-noise ratio.
- Multitalker babble at a fixed level.
- Descending paradigm –24-to 0-dB S/N in 4-dB decrements.
- Scored in terms of signal-to-noise ratio at the 50% point.
    - Spearman-Kärber equation
    - 50% = 26 –(# correct)(0.8)
    - The "0.8" is the attenuation step size (4 dB) divided by the number of words per step (5)

Binaural Test Setup:

- Use one channel and present stimuli to both ears at the same time.
- Whichever channel you are using, set the audiometer to play from CD1 (or Ext. A from the GSI)
- Set level to 70 dB HL and leave it. The signal-to-noise ratio changes on its own.
- Administer two lists (35 words per list).
- Stop administration if all of the words at a given S/N (all 5 words) are incorrect.
- Get the score by first adding up all correct responses. Then use the table on the right side of the page to find the corresponding S/N threshold.

Patient Instructions:

For the following test, you will hear a woman's voice and she will say something like, "say the word 'boy'" or "say the word 'dog'." Your job is to only repeat back the word she told you to say. You will also hear people talking in the background. Try to ignore the extra people in the background, and only listen for the word you have to repeat. Even if you aren't sure what the word is, go ahead and guess. Do you have any questions?

Words-in-Noise (WIN)

Name_____ Date_____

Ear_____Level_____

Track 25, List 1, Random 1

24-dB S/B			12-dB S/B			0-dB S/B		
1	pain		16	hate		31	gaze	
2	youth		17	shack		32	life	
3	wheat		18	tool		33	get	
4	dodge		19	voice		34	read	
5	cool		20	rush		35	bath	
20-dB S/B			8-dB S/B					
6	ditch		21	turn		# Correct		
7	ring		22	young		Threshold (50%) dB S/B		
8	kick		23	bite				
9	chair		24	pick				
10	luck		25	half				
16-dB S/B			4-dB S/B					
11	base		26	far				
12	wire		27	learn				
13	red		28	mood				
14	time		29	talk				
15	judge		30	note				

Ear_____Level_____

Track 26, List 2, Random 1

24-dB S/B			12-dB S/B			0-dB S/B		
1	food		16	good		31	back	
2	road		17	search		32	dab	
3	juice		18	pass		33	kill	
4	late		19	witch		34	nice	
5	hire		20	chief		35	calm	
20-dB S/B			8-dB S/B					
6	tire		21	sour		# Correct		
7	such		22	doll		Threshold (50%) dB S/B		
8	shawl		23	deep				
9	haze		24	soap				
10	gun		25	make				
16-dB S/B			4-dB S/B					
11	live		26	beg				
12	date		27	mess				
13	gas		28	long				
14	have		29	mouse				
15	dog		30	sheep				

	# Correct	Threshold
	1	25.2
	2	24.4
	3	23.6
PROFOUND	4	22.8
	5	22.0
	6	21.2
	7	20.4
	8	19.6
	9	18.8
	10	18.0
SEVERE	11	17.2
	12	16.4
	13	15.6
	14	14.8
	15	14.0
	16	13.2
MODERATE	17	12.4
	18	11.6
	19	10.8
	20	10.0
	21	9.2
MILD	22	8.4
	23	7.6
	24	6.8
	25	6.0
	26	5.2
	27	4.4
	28	3.6
	29	2.8
NORMAL	30	2.0
	31	1.2
	32	0.4
	33	-0.4
	34	-1.2
	35	-2.0

Subject Number: _____ Date _____ Ear _____ Presentation Level _____

Pre-test Track 14 Northwestern No. 6, List 5

45% Compressed

1. Hall	_____	26. Match	_____
2. Shirt	_____	27. Chair	_____
3. Rough	_____	28. Bought	_____
4. Vote	_____	29. Thought	_____
5. Dip	_____	30. Gaze	_____
6. Join	_____	31. Voice	_____
7. Peg	_____	32. Rot	_____
8. Neat	_____	33. Shack	_____
9. Wheat	_____	34. Pike	_____
10. Get	_____	35. Merge	_____
11. Doll	_____	36. Numb	_____
12. Chat	_____	37. Keep	_____
13. Hire	_____	38. White	_____
14. Bar	_____	39. Said	_____
15. When	_____	40. Room	_____
16. Rat	_____	41. Which	_____
17. Five	_____	42. Moon	_____
18. Team	_____	43. Hurl	_____
19. Germ	_____	44. Raid	_____
20. Ring	_____	45. Jar	_____
21. Talk	_____	46. Met	_____
22. Date	_____	47. Take	_____
23. Youth	_____	48. Shout	_____
24. Far	_____	49. Pool	_____
25. Deep	_____	50. Boat	_____

Total Score: _____/ 50

Percentage: _____

Subject Number: _____ Date _____ Ear _____ Presentation Level _____

Pre-Test Track 16 Northwestern No. 6, List 7A

65% Compressed

1. Jug _____
2. Chief _____
3. Reach _____
4. Gap _____
5. Hurl _____
6. Pole _____
7. Late _____
8. Hall _____
9. Yearn _____
10. Met _____
11. Kill _____
12. Bean _____
13. Pike _____
14. Cheek _____
15. Goose _____
16. Wire _____
17. Vine _____
18. Kite _____
19. Kick _____
20. Have _____
21. Pearl _____
22. Get _____
23. Whip _____
24. Said _____
25. Food _____
26. Week-Weak _____
27. Raise _____
28. Mop _____
29. Room _____
30. Far _____
31. Shout _____
32. Raid _____
33. Voice _____
34. Sure _____
35. Note _____
36. Chain _____
37. Luck _____
38. Bought _____
39. Thin _____
40. Rain _____
41. Shirt _____
42. Dip _____
43. Doll _____
44. Limb _____
45. Haze _____
46. Lot _____
47. Gas _____
48. South _____
49. Size _____
50. Live _____

Total Score: _____/ 50

Percentage: _____

Baseline_____ Post-test_____ Subject #:_____
Date:_____

Synthetic Sentence Identification with Ipsilateral Competing Message

1. Small boat with a picture has become
2. Built the government with the force almost
3. Go change your car color is red
4. Forward march said the boy had a
5. March around without a care in your
6. That neighbor who said business is better
7. Battle cry and be better than ever
8. Down by the time is real enough
9. Agree with him only to find out
10. Women view men with green paper should

Jerger, J., Speaks, C., & Trammell, J. L. (1968). A new approach to speech audiometry. *Journal of Speech and Hearing Disorders, 33*, 318-328.

Baseline_____ Post-test_____ Subject #:_____
Date:_____

Synthetic Sentence Identification with Ipsilateral Competing Message

Which ear was given first? _____
(For participants with odd subject numbers start with left ear and for those with even subject numbers start with right ear first.)

Practice	Left Ear, Form G	Right Ear, Form H
1. _____	1. _____	1. _____
2. _____	2. _____	2. _____
3. _____	3. _____	3. _____
4. _____	4. _____	4. _____
5. _____	5. _____	5. _____
6. _____	6. _____	6. _____
7. _____	7. _____	7. _____
8. _____	8. _____	8. _____
9. _____	9. _____	9. _____
10._____	10._____	10._____

Form G
percentage correct:
_____

Form H
percentage correct:
_____

Total
percentage correct:
_____

Jerger, J., Speaks, C., & Trammell, J. L. (1968). A new approach to speech audiometry. *Journal of Speech and Hearing Disorders, 33*, 318-328.

Baseline_____ Post-test_____ Subject #: _____
Date: _____

1. Small boat with picture has become.
2. Built by the government with the force almost.
3. Go change your car color is red.
4. Down by the time is real enough.
5. Agree with him only to find out.
6. Women view men with green paper should.

Fifer, R. C., Jerger, J. F., Berlin, C. I., Tobey, E. A., & Campbell, J. C. (1983). Development of a dichotic sentence identification test for hearing-impaired adults. *Ear and Hearing, 4*(6), 300-305.

Baseline_____ Post-test_____ Subject #: _____
Date: _____

Dichotic Sentence Identification

1.	_____ _____	16.	_____ _____
2.	_____ _____	17.	_____ _____
3.	_____ _____	18.	_____ _____
4.	_____ _____	19.	_____ _____
5.	_____ _____	20.	_____ _____
6.	_____ _____	21.	_____ _____
7.	_____ _____	22.	_____ _____
8.	_____ _____	23.	_____ _____
9.	_____ _____	24.	_____ _____
10.	_____ _____	25.	_____ _____
11.	_____ _____	26.	_____ _____
12.	_____ _____	27.	_____ _____
13.	_____ _____	28.	_____ _____
14.	_____ _____	29.	_____ _____
15.	_____ _____	30.	_____ _____

Number correct pairs out of 30: _____ Percentage correct: _____

Fifer, R. C., Jerger, J. F., Berlin, C. I., Tobey, E. A., & Campbell, J. C. (1983). Development of a dichotic sentence identification test for hearing-impaired adults. *Ear and Hearing, 4*(6), 300-305.

Dichotic Digits Free Recall

Setup:

Use both channels on the audiometer.

Channel 1 is always the LE (ext. A) and Channel 2 is always the RE (ext. B).

Both ears are set to 50 dB SL re: SRT

Administer the circled track #.

Score each ear independently and find a percent correct score per ear.

Add up all correctly repeated numbers and divide by the total number of numbers (50).

This is your percent correct score for that ear.

Patient Instructions:

You will hear a man say 4 numbers. 2 numbers will be in your left ear and 2 numbers will be in your right ear at the same time. Wait until he says all 4 numbers, and then repeat all of them back to me the best you can. It doesn't matter what order you repeat them. Do you have any questions?

Dichotic Digits Free Recall 2-pair

Name:_____ Date:_____

2-PAIR DIGITS–TRACK 3				
#	Left	Total Correct	Right	Total Correct
1	4, 3		1, 6	
2	3, 1		9, 10	
3	9, 6		1, 5	
4	2, 10		6, 8	
5	4, 8		6, 9	
6	9, 1		10, 2	
7	2, 4		9, 10	
8	1, 9		8, 6	
9	2, 4		3, 9	
10	1, 4		10, 5	
11	2, 5		1, 3	
12	4, 5		2, 6	
13	3, 10		5, 6	
14	4, 1		9, 5	
15	4, 5		3, 8	
16	9, 5		4, 1	
17	4, 5		10, 2	
18	9, 8		3, 4	
19	9, 10		8, 5	
20	8, 6		4, 1	
21	6, 8		10, 2	
22	9, 1		2, 8	
23	6, 9		3, 1	
24	1, 2		3, 9	
25	5, 3		2, 1	
SUMS				

Percent Correct Left (Left Sum/25*100) _____

Percent Correct Right (Right Sum/25*100) _____

Percent Correct Total ((Left Sum+Right Sum)/50*100) _____

C:\Users\Amy's computer\Downloads\DD- Track 3 (FR).docx

Hearing Handicap Inventory <65 years and 65+ years

INSTRUCTIONS: The purpose of this scale is to identify the problems your hearing loss may be causing you. Please select NO, SOMETIMES, or YES for each question. Do not skip a question if you avoid a situation because of your hearing problem. If you wear hearing instruments, please answer the way you hear without hearing instruments.

Question	No	Sometimes	Yes
Does a hearing problem cause you to feel embarrassed when you meet new people?			
Does a hearing problem cause you to feel frustrated when talking to a member of your family?			
Does a hearing problem cause you difficulty hearing/understanding coworkers, clients, or customers?			
Do you feel handicapped by a hearing problem?			
Does a hearing problem cause you difficulty when visiting friends, relatives, or neighbors?			
Does a hearing problem cause you difficulty in the movies or theaters?			
Does a hearing problem cause you to have arguments with family members?			
Does a hearing problem cause you difficulty when listening to television or radio?			
Do you feel that any difficulty with your hearing limits/hampers your personal or social life?			
Does a hearing problem cause you difficulty when in a meeting or conference?			

TOTAL SCORE	IMPAIRMENT
0–8	No Handicap
10 – 24	Mild-Moderate Handicap
25 – 40	Severe Handicap

Total 'No'
Total 'Sometimes' Total 'Yes' TOTAL SCORE

_____ x 0 = _____ _____ x 2 = _____ _____ x 4 = _____

Question	No	Sometimes	Yes
Does a hearing problem cause you to feel embarrassed when you meet new people?			
Does a hearing problem cause you to feel frustrated when talking to a member of your family?			
Do you have difficulty hearing when someone speaks in a whisper?			
Do you feel handicapped by a hearing problem?			
Does a hearing problem cause you difficulty when visiting friends, relatives, or neighbors?			
Does a hearing problem cause you to attend religious services less often than you would like?			
Does a hearing problem cause you to have arguments with family members?			
Does a hearing problem cause you difficulty when listening to television or radio?			
Do you feel that any difficulty with your hearing limits/hampers your personal or social life?			
Does a hearing problem cause you difficulty when in a restaurant with relatives or friends?			

TOTAL SCORE	IMPAIRMENT
0–8	No Handicap
10 – 24	Mild-Moderate Handicap
25 – 40	Severe Handicap

Total 'No'
Total 'Sometimes' Total 'Yes' TOTAL SCORE

_____ x 0 = _____ _____ x 2 = _____ _____ x 4 = _____

_____

Ages 65+

Appendix C: NIH Toolbox Information and Cognitive Performance Instruments

NIH Toolbox Overview

NIH Toolbox
The NIH Toolbox is a multidimensional set of brief royalty-free measures that researchers can use to assess cognitive, sensory, motor and emotional function in people ages 3-85. This suite of measures can be administered to study participants in two hours or less, across diverse study designs and settings. The measures have been normed and validated in a broad sample of the U.S. population.

NIH Toolbox History
In 2004, the 15 Institutes, Centers and Offices at NIH that support neuroscience research formed a coalition called the Blueprint for Neuroscience Research. The NIH Blueprint goal is to develop new tools, resources, and training opportunities to accelerate the pace of discovery in neuroscience research. Because the research community had long sought the development of standard instruments to measure cognitive and emotional health, in 2006 the NIH Blueprint awarded a contract to develop an innovative approach to meet this need. Under the leadership of Dr. Richard Gershon, Principal Investigator, a team of more than 300 scientists from nearly 100 academic institutions were charged with developing a set of state-of-the-art tools to enhance data collection in large cohort studies and to advance the neurobehavioral research enterprise.

What is the NIH Toolbox?
The NIH Toolbox provides a standard set of royalty-free, comprehensive assessment tools that can be used by researchers and clinicians in a variety of settings, with a particular emphasis on measuring outcomes in longitudinal epidemiologic studies and prevention or intervention trials. The battery has been normed and validated across the lifespan in subjects age 3-85 and its use ensures that assessment methods and results can be used for comparisons across existing and future studies. By providing a "common currency" for the study of neurological research, the NIH Toolbox enables economies of scale and enhances efficiency. The NIH Toolbox is capable of monitoring neurological and behavioral function over time, and measuring key constructs across developmental stages.

The NIH Toolbox Batteries
The NIH Toolbox can be administered within two hours and divides tests into four domain batteries: Cognition, Sensation, Motor and Emotion. In addition, within some domains, there are supplemental measures that can be administered (please visit www.nihtoolbox.org for more information on these supplemental measures).

Impact of the NIH Toolbox on Neurological Research
Prior to the NIH Toolbox, there were many studies that collected information on aspects of neural function (cognition, sensation, motor, emotion) with little uniformity among the measures used to capture these constructs. Moreover, capturing information on all four domains within a study would be costly in terms of time and subject burden. With the advent of the NIH Toolbox, researchers can now assess function using a common metric and can "crosswalk" among measures, supporting the pooling and sharing of large data sets. The NIH Toolbox will support scientific discovery by bringing a common language to important research questions– both with respect to the primary study aims and to those arising from secondary data analyses. The four batteries promise to provide researchers with streamlined measures that have minimal subject burden and cost.

Selection of the NIH Toolbox Domains and Sub-domains
NIH Project Team members determined the breadth of the NIH Toolbox. Four domains were selected: Cognition, Motor, Emotion, and Sensation. Initial literature and database reviews and a Request for Information of NIH-funded researchers identified the sub-domains for inclusion in the NIH Toolbox, existing measures relevant to the project goals, and criteria for instrument selection. NIH Project Team members, external content experts, and contract scientists met at a follow-up consensus meeting to discuss potential sub-domains along with the criteria affecting instrument selection, creation, and norming. Additional expert interviews were undertaken to gather more detailed information from clinical and scientific experts to help further refine the list of possible sub-domains. A second consensus group meeting was held and results directed the selection of the sub-domains within each core domain area to be measured in the final NIH Toolbox.

 This project is funded in whole or in part with Federal funds from the Blueprint for Neuroscience Research and the Office of Behavioral and Social Sciences Research, National Institutes of Health, under Contract No. HHS-N-260-2006-00007-C

NIH Toolbox Overview

Selection of Measures for the NIH Toolbox
More than 1,400 existing measures were identified and evaluated for inclusion in the NIH Toolbox. The selection criteria included a measure's applicability across the life span, psychometric soundness, brevity, ease of use, applicability in diverse settings and with different groups, and lack of intellectual property constraints. There was also a preference for instruments that were already validated and normed for use with individuals between 3 and 85 years old. Results of the instrument selection process greatly facilitated the drafting of plans to develop the NIH Toolbox measures.

Validation
Validation studies were conducted for all NIH Toolbox measures to assure that these important tools for research met rigorous scientific standards. Studies were conducted across the entire age range, typically included 450-500 subjects, and were statistically compared against "gold standard" measures wherever available. For tests using Item Response Theory approaches to scoring, calibration samples generally included several thousand participants, ensuring robust models. In total, data was collected from more than 16,000 subjects as part of field-test, calibration and validation activities.

Norming
NIH Toolbox conducted a large national standardization study in both English and Spanish languages to allow for normative comparisons on each assessment. A sample of 4,859 participants, ages 3-85 – representative of the U.S. population based on gender, race/ethnicity, and socioeconomic status – was administered all of the NIH Toolbox measures at sites around the country. NIH Toolbox normative scores are now available for each year of age from 3 through 17, as well as for ages 18-29, 30-39, 40-49, 50-59, 60-69, 70-79, and 80-85, allowing for targeted, accurate comparisons for any research study participant groups against the U.S. population.

Advanced Measurement Techniques
The NIH Toolbox measures utilize several advanced approaches in item development, test construction, and scoring. Two of these are Item Response Theory (IRT) and Computer Adaptive Testing (CAT). Item Response Theory allows tests to be brief, yet still precise and valid. Using IRT methodology, sets of items are calibrated along a continuum that covers the full range of the construct to be measured. This calibrated set of items enables the creation of Computer Adaptive Testing. CAT is a specialized type of computer-based testing that enables frequent assessments and immediate feedback with minimal burden on participants ***and*** precise evaluation at the individual level. Users can administer short, unique tests to every individual, with reliability and scores equivalent to longer, fixed-length assessments.

Early Childhood Use
NIH Toolbox measure development focused special attention on assessing young children, to ensure that all tests given are developmentally appropriate for ages 3-7. A special team of early childhood assessment consultants was engaged to provide testing guidelines for the very young, to offer input on measure development, and to review all NIH Toolbox measures to ensure they fit the needs of young children.

Before NIH Toolbox

- Custom measures could not easily be compared across studies
- Assessments typically limited to looking at cognitive variables
- Expensive equipment and per-subject royalty fees
- Time-consuming measures often required highly trained administrators

After NIH Toolbox

- Standardized measures easily compared across studies. Validated against "gold standard" instruments
- Easily incorporate multiple areas of neurological functioning (motor, emotion, sensory)
- Inexpensive equipment, no royalties, low per-subject costs (per-subject costs limited to taste and olfaction assessments)
- Cutting-edge, brief, psychometrically sound measures can be administered with minimal expertise

 This project is funded in whole or in part with Federal funds from the Blueprint for Neuroscience Research and the Office of Behavioral and Social Sciences Research, National Institutes of Health, under Contract No. HHS-N-260-2006-00007-C

NIH Toolbox is powered by Assessment Center

Assessment Center℠ is the browser-based research management software application where you can access, practice, and administer NIH Toolbox measures. It is a free, online research management tool that enables researchers to create study-specific websites for capturing participant data securely. Studies can include measures within the Assessment Center library as well as custom measures created or entered by the researcher.

NIH TOOLBOX DOMAINS AND MEASURES

Cognition

NIH Toolbox Cognition Battery
This battery, recommended for ages 7+, consists of tests to assess Executive Function, Attention, Episodic Memory, Language, Processing Speed and Working Memory. Administering this battery will yield the following summary scores, in addition to individual measure scores: Cognitive Function Composite Score, Fluid Cognition Composite Score (includes DCCS, Flanker, Picture Sequence Memory, List Sorting, and Pattern Comparison measures), and Crystallized Cognition Composite Score (includes Picture Vocabulary and Reading Recognition measures).

NIH Toolbox Early Childhood Cognition Battery
This battery, recommended for ages 3-6, includes the DCCS, Flanker, Picture Sequence Memory, and Picture Vocabulary measures. In addition to individual measure scores, administering this battery will yield an Early Childhood Composite Score.

The Cognition Domain includes measures of:

EXECUTIVE FUNCTION
Measured by: NIH Toolbox Flanker Inhibitory Control & Attention Test and NIH Toolbox Dimensional Change Card Sort Test.

ATTENTION
Measured by: NIH Toolbox Flanker Inhibitory Control and Attention Test

EPISODIC MEMORY
Measured by: NIH Toolbox Picture Sequence Memory Test

LANGUAGE
Measured by: NIH Toolbox Picture Vocabulary Test and NIH Toolbox Oral Reading Recognition Test

PROCESSING SPEED
Measured by: NIH Toolbox Pattern Comparison Processing Speed Test

WORKING MEMORY
Measured by: NIH Toolbox List Sorting Working Memory Test

SUPPLEMENTAL MEASURES
NIH Toolbox Oral Symbol Digit Test
NIH Toolbox Auditory Verbal Learning Test (Rey)

 This project is funded in whole or in part with Federal funds from the Blueprint for Neuroscience Research and the Office of Behavioral and Social Sciences Research, National Institutes of Health, under Contract No. HHS-N-260-2006-00007-C

Sensation

NIH Toolbox Sensation and Pain Battery
This battery, recommended for ages 7+, consists of tests to assess Audition, Visual Acuity, Vestibular Balance, Olfaction, Taste (Ages 12+) and Pain (Ages 18+).

NIH Toolbox Early Childhood Sensation Battery
This battery, recommended for ages 3-6, includes measures of Visual Acuity, Vestibular Balance and Olfaction.

The Sensation Domain includes measures of:

AUDITION
Measured by:
NIH Toolbox Words-in-Noise Test

VISION
Measured by:
NIH Toolbox Visual Acuity Test

VESTIBULAR
Measured by:
NIH Toolbox Dynamic Visual Acuity Test
NIH Toolbox Standing Balance Test, (contained within the NIH Toolbox Motor battery)

OLFACTION
Measured by: NIH Toolbox Odor Identification Test

TASTE
Measured by: NIH Toolbox Taste Intensity Test

PAIN
Measured by: NIH Toolbox Pain Intensity Survey and NIH Toolbox Pain Interference Survey

Supplemental Measures
NIH Toolbox Hearing Handicap Ages 18-64
NIH Toolbox Hearing Handicap Age 65+
NIH Toolbox Vision-Related QOL Color Vision Age 18+
NIH Toolbox Vision-Related QOL Distance Vision Age 18+
NIH Toolbox Vision-Related QOL Near Vision Age 18+
NIH Toolbox Vision-Related QOL Ocular Symptoms Age 18+
NIH Toolbox Vision-Related QOL Psychosocial Age 18+
NIH Toolbox Vision-Related QOL Role Performance Age 18+

 This project is funded in whole or in part with Federal funds from the Blueprint for Neuroscience Research and the Office of Behavioral and Social Sciences Research, National Institutes of Health, under Contract No. HHS-N-260-2006-00007-C

Participant #:_____ Date: _____

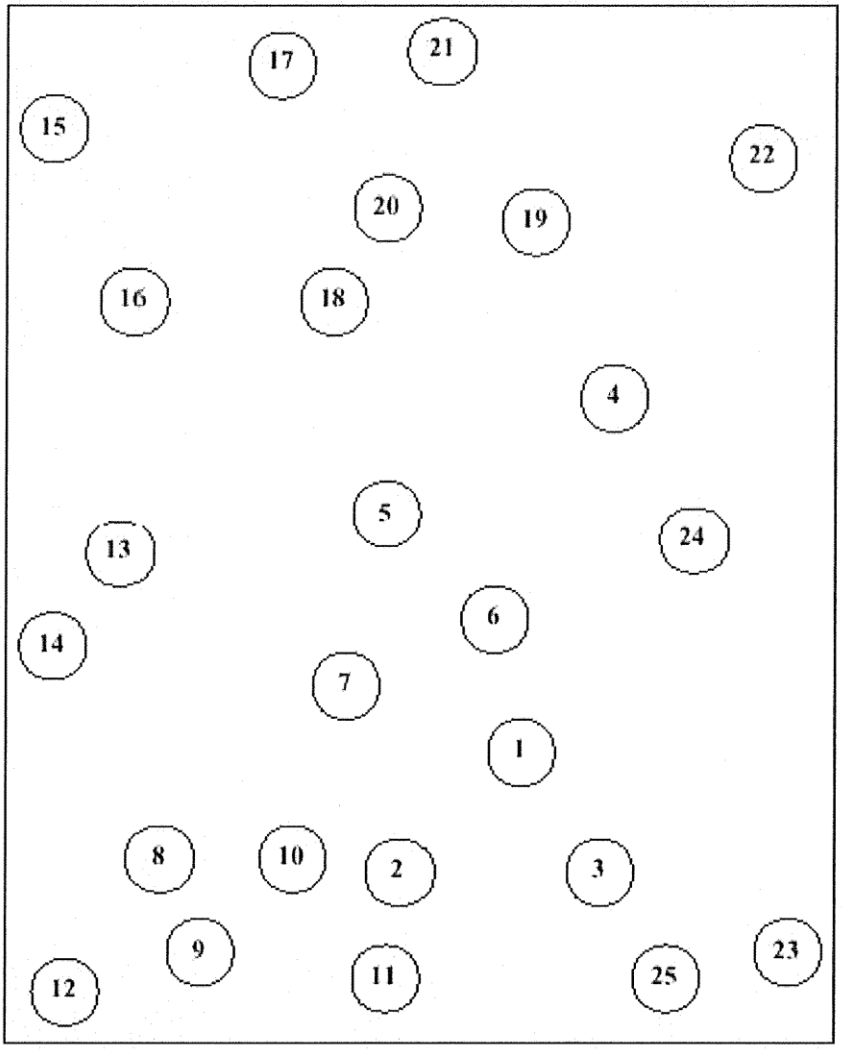
Controlled Oral Word Association Test

P	R	W
1.)_____	1.)_____	1.)_____
2.)_____	2.)_____	2.)_____
3.)_____	3.)_____	3.)_____
4.)_____	4.)_____	4.)_____
5.)_____	5.)_____	5.)_____
6.)_____	6.)_____	6.)_____
7.)_____	7.)_____	7.)_____
8.)_____	8.)_____	8.)_____
9.)_____	9.)_____	9.)_____
10.)_____	10.)_____	10.)_____
11.)_____	11.)_____	11.)_____
12.)_____	12.)_____	12.)_____
13.)_____	13.)_____	13.)_____
14.)_____	14.)_____	14.)_____
15.)_____	15.)_____	15.)_____
16.)_____	16.)_____	16.)_____
17.)_____	17.)_____	17.)_____
18.)_____	18.)_____	18.)_____
19.)_____	19.)_____	19.)_____
20.)_____	20.)_____	20.)_____
21.)_____	21.)_____	21.)_____
22.)_____	22.)_____	22.)_____
23.)_____	23.)_____	23.)_____
24.)_____	24.)_____	24.)_____
25.)_____	25.)_____	25.)_____
26.)_____	26.)_____	26.)_____
27.)_____	27.)_____	27.)_____
28.)_____	28.)_____	28.)_____
29.)_____	29.)_____	29.)_____
30.)_____	30.)_____	30.)_____

The Relationship Between Visual Status and Cognitive Performance
2013 University of South Florida College of Nursing

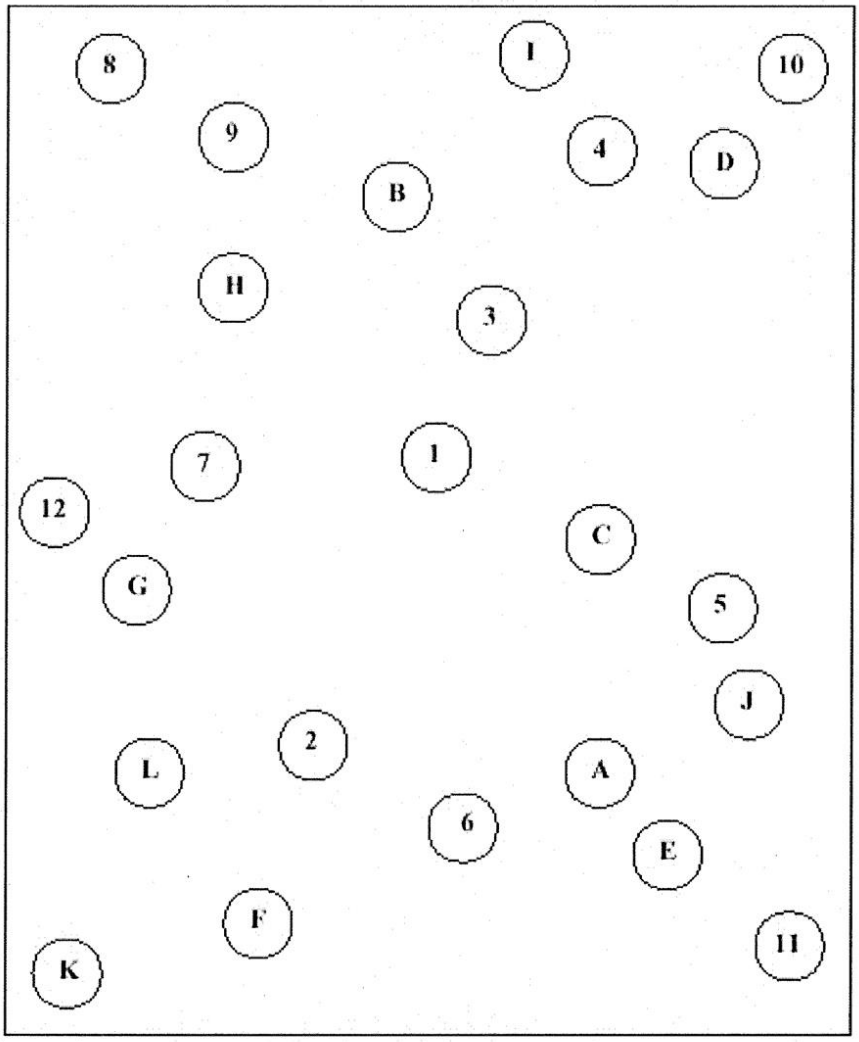
Trail Making Test Part A

Patient's ID# _____ Date: _____



Trail Making Test Part B

Patient's ID# _____ Date: _____



Subject ID: _____
Date: _____

Vision and Cognition Study
Auditory Tests
Data Sheet

ATTR Gap Detection Thresholds
Use "Standard 2 Alternative Forced Choice"

Run	Within-Channel	Across-Channel Falling
1		
2		
3		

*3rd Run only if necessary

Within Channel Gap Detection

Run	Starting Gap Duration (msec)
1	
2	
3	

Across Channel Gap Detection

Run	Starting Gap Duration (msec)
1	
2	
3	

Comments_____

Version #1 06/28/2013

Appendix D: Geriatric Depression Scale

Geriatric Depression Scale (Short Form)

Patient's Name: _____ Date: _____

Instructions: Choose the best answer for how you felt over the past week. Note: when asking the patient to complete the form, provide the self-rated form (included on the following page).

No.	Question	Answer	Score
1.	Are you basically satisfied with your life?	YES / ***NO***	
2.	Have you dropped many of your activities and interests?	***YES*** / NO	
3.	Do you feel that your life is empty?	***YES*** / NO	
4.	Do you often get bored?	***YES*** / NO	
5.	Are you in good spirits most of the time?	YES / ***NO***	
6.	Are you afraid that something bad is going to happen to you?	***YES*** / NO	
7.	Do you feel happy most of the time?	YES / ***NO***	
8.	Do you often feel helpless?	***YES*** / NO	
9.	Do you prefer to stay at home, rather than going out and doing new things?	***YES*** / NO	
10.	Do you feel you have more problems with memory than most people?	***YES*** / NO	
11.	Do you think it is wonderful to be alive?	YES / ***NO***	
12.	Do you feel pretty worthless the way you are now?	***YES*** / NO	
13.	Do you feel full of energy?	YES / ***NO***	
14.	Do you feel that your situation is hopeless?	***YES*** / NO	
15.	Do you think that most people are better off than you are?	***YES*** / NO	
		TOTAL	

(Sheikh & Yesavage, 1986)

Scoring:

Answers indicating depression are in bold and italicized; score one point for each one selected. A score of 0 to 5 is normal. A score greater than 5 suggests depression.

Sources:

- Sheikh JI, Yesavage JA. Geriatric Depression Scale (GDS): recent evidence and development of a shorter version. *Clin Gerontol*. 1986 June;5(1/2):165-173.
- Yesavage JA. Geriatric Depression Scale. *Psychopharmacol Bull*. 1988;24(4):709-711.
- Yesavage JA, Brink TL, Rose TL, et al. Development and validation of a geriatric depression screening scale: a preliminary report. *J Psychiatr Res*. 1982-83;17(1):37-49.

Appendix E: Demographic/General Health Questionnaire

Participant # _____ Date: _____

DEMOGRAPHIC INFORMATION

1. Name_____

2. Date of Birth **(month, day, year)**_____

3. Sex:
   1._____Male
   2._____Female

4. Race:
   1._____White
   2._____Black
   3._____American Indian
   4._____Asian or Pacific Islander
   5._____Other (specify:)_____

5. Ethnicity: Do you consider yourself Hispanic or Latino/a?
   1._____No
   2._____Yes

6. Marital Status:
   1._____Married
   2._____Single
   3._____Living separately but not divorced
   4._____Divorced
   5._____Widowed

7. Social Support: Do you live:
   1._____Alone
   2._____with your spouse
   3._____with another family member
   if yes, please indicate relation_____
   4._____with a friend
   5._____other, please specify_____

8. Last level of education you completed: **(circle one)**

Grade (Elementary - High School)												College				Masters		Ph.D./ Prof.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20

Participant # _____ Date: _____

General Health Questionnaire

1. In general, would you say that your health is:

1) Excellent 2) Very Good 3) Good 4) Fair 5) Poor 7) Don't know 1. ☐

Has a doctor ever told you that you have:

2	Heart problems (e.g. pacemaker, heart attack, open heart surgery)	1=Yes	2=No
3	Circulation problems (e.g., arteriosclerosis, atherosclerosis, clotting problems)	1=Yes	2=No
4	High blood pressure	1=Yes	2=No
5	Low blood pressure	1=Yes	2=No
6	Neurological problems (e.g., stroke, Parkinson's, Alzheimer's, dementia, multiple sclerosis)	1=Yes	2=No
7	Diabetes	1=Yes	2=No
8	Arthritis	1=Yes	2=No
9	Osteoporosis	1=Yes	2=No
10	Cancer	1=Yes	2=No
11	Chronic Pulmonary (lung) problems (e.g., emphysema, asthma, tuberculosis, asbestosis)	1=Yes	2=No
12	Digestive problems (e.g., stomach ulcer, gastrointestinal problems, hiatal hernia)	1=Yes	2=No
13	Urinary problems (e.g., urinary tract infections, incontinence, prostate problems)	1=Yes	2=No
14	Kidney problems	1=Yes	2=No
15	Hearing impairment	1=Yes	2=No
16	Other -- Specify here:	1=Yes	2=No

17. Have you fallen in the last six months? 1=Yes 2=No 17. ☐

17a. If YES, how many times? _____ 17a. ☐

18. Have you ever had a driver's license? 1=Yes 2=No 18. ☐

18a. Do you currently have a driver's license? 1=Yes 2=No 18a. ☐

18b. Do you currently drive? 1=Yes 2=No 18b. ☐

18c. If NO: Why did you stop?
Text box: _____

18d. Do you currently own a vehicle? 1=Yes 2=No 18d. ☐

Appendix F: IRB Approval

USF
UNIVERSITY OF
SOUTH FLORIDA

RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-4799
(813) 974-5638 • FAX (813) 974-7091

10/22/2014

Amanda Elliott, PhD
College of Nursing
USF College of Nursing
12901 Bruce B. Downs Blvd MDC22
Tampa, FL 33612-4766

RE: **Expedited Approval for Amendment**
IRB#: Ame7_Pro00011063
Title: The Relationship between Visual Status and Cognitive Performance in Older Adults

Dear Dr. Elliott:

On 10/22/2014, the Institutional Review Board (IRB) reviewed and **APPROVED** your Amendment. The submitted request has been approved for the following:

Approved Item(s):
Protocol Document(s):
Full Dissertation Proposal_Daugherty

Other Document(s):
Data Collection Form_Daugherty

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

John A Schinka, Ph.D.

John Schinka, Ph.D., Chairperson
USF Institutional Review Board