2022

Examining the Utility of Auditory Processing Tests in Clinical Neuropsychology

Behnaz Sarlak
Walden University

Walden University

College of Allied Health

This is to certify that the doctoral dissertation by

Behnaz Sarlak

has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

Review Committee
Dr. Tracy Marsh, Committee Chairperson, Psychology Faculty
Dr. Lisa Scharff, Committee Member, Psychology Faculty
Dr. Chet Lesniak, University Reviewer, Psychology Faculty

Chief Academic Officer and Provost
Sue Subocz, Ph.D.

Walden University
2022

Abstract

Examining the Utility of Auditory Processing Tests in Clinical Neuropsychology

by

Behnaz Sarlak

MS, Walden University, 2017

MD, Azad Tehran Medical Branch University, 1996

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Clinical Psychology

Walden University

August 2022

Abstract

Memory loss has been a concern in patients with neurodegenerative disease, as it can cause cognitive problems such as speech and language issues. Clinicians need to use reliable, assessable, noninvasive, repeatable, and inexpensive tools to diagnose memory impairment. There is a gap in the literature on whether specific cognitive tests provide valid, reliable, cost and time-effective methods for screening for dementia. The purpose of this quantitative correlational study was to examine if the Seashore, the Speech-Sound Perception Test, the SCAN-A test, Logical Memory, Verbal Paired Associates, and Digit Span Test can predict whether an individual has been diagnosed with Alzheimer's disease (AD). Theory of mind served as the theoretical framework for this study, which used archival data from 157 individuals over age 30 years who were referred for a neuropsychological evaluation from 2015 to 2021 at private consulting psychology practice in a large urban area. Binary logistic regression was used to determine if scores on the Seashore, the Speech-Sound Perception Test, the SCAN-A test, Logical Memory, Verbal Paired Associates, and Digit Span Test were able to differentiate between those with a diagnosis of Alzheimer's and those without. Results indicated that below standard SCAN-A test scores (less than 85) could significantly predict patients with an AD diagnosis regardless of age. In contrast, cases without AD demonstrated a strong association between score and age. This study can promote positive social change agendas by introducing more available tools and cognitive tests for diagnosing AD patients early in their disease.

Examining the Utility of Auditory Processing Tests in Clinical Neuropsychology

by

Behnaz Sarlak

MS, Walden University, 2017

MD, Azad Tehran Medical Branch University, 1996

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Clinical Psychology

Walden University

March 2022

Acknowledgments

To my husband, Abbie. Your love, encouragement, patience, and generosity made this journey very enjoyable for me.

To my stepchildren, Neiman and Dr. Melody Gougerchian. I am grateful to have you in my life and thank you for your support and encouragement. To my siblings who give meaning to my life, thank you.

To Dr. Tracy Marsh and Dr. Lisa Scharff, please accept my sincere thanks for your support, guidance, patience, and encouragement, which made it possible for me to complete this dissertation. I am grateful for all your valuable advice and constructive criticism.

I would like to express my deep gratitude to Dr. Edward Dunbar for his continued support, wisdom, and data, which were a tremendous help for this journey.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction to the Study

Memory impairment represents a major cognitive problem for patients with neurodegenerative disease, such as individuals with Alzheimer's disease (AD), dementia, Parkinson's, and other degenerative diseases (Rohrer et al., 2008). For example, patients who have dementia because of neurodegenerative diseases have speech and language problems (Al-Hameed et al., 2019). Why word-finding is difficult for these patients is not very clear (Rohrer et al., 2008), but memory issues are one of the most common concerns of individuals as they age. Al-Hameed et al. (2019) agreed that earlier diagnosis of neurodegenerative disorders and treatment could be more effective and prevent irreversible brain changes.

On a daily basis, large numbers of individuals who have memory concerns refer to their primary care doctors for evaluation and treatment (Al-Hameed et al., 2019). However, identification of neurodegenerative disorders in the early stages can be challenging because of the limitations of routine screening. Most of the biomarkers that are employed to diagnose neurodegenerative disorders, such as amyloid positron emission tomography which can identify high-risk patients with progressive cognitive decline (e.g., AD), are costly and available only in narrow contexts (Al-Hameed et al., 2019). Another important issue is that some of these diagnostic tests can be invasive and should not be used as screening tests (Al-Hameed et al., 2019). Certain tools can be used to screen individuals for dementia. For example, Dementia-Detection (DemTect; Larner, 2007) is a short screening test with five subtests that takes 5 to 10 minutes to administer; also, the Montreal Cognitive Assessment (MoCA; Sammer & Lenz, 2020) is a brief cognitive test that takes 10 to 15 minutes to administer and identifies individuals with AD

or mild cognitive impairment. However, these tests only screen for learning effects, and their validity is limited (Al-Hameed et al., 2019, p. 2). Al-Hameed et al. (2019) stated that since these tests have limited validity and poor specificity and have not been tested in individuals with functional memory disorder (FMD), there remains a need for additional reliable, assessable, noninvasive, repeatable, and inexpensive tools to help clinicians diagnose neurodegenerative disease in patients. Adding some other quick and simple tests such as the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), and the Seashore Rhythm (Seashore) Test (Seashore, 1915) to other diagnostic tools such as Logical Memory (WMS-IV) (Wechsler, 2009), Verbal Paired Associates (WMS-IV) (Wechsler, 2009), and Digit Span (WAIS-IV) (Wechsler, 2008) may detect neurodegenerative diseases at earlier stages.

Background

For decades, researchers and clinicians have used the SCAN-A (Keith, 1994) for Adolescents and Adults as a component of neuropsychological testing. Keith (1994) stated that the SCAN-A is useful in identifying auditory processing issues in adolescents and adults. Researchers use this test to describe auditory process abilities, central auditory abilities, and functional impairment in individuals with chronic central nervous system disease (Keith, 1994). Requiring almost 20 minutes to administer, this test is an additional tool for diagnosing learning disability in adults. Ghasemy et al. (2019) believed that sustained auditory attention is essential in individuals' communication and learning processes. Sustained attention, along with vigilance, play crucial roles in attention abilities. If sustained auditory attention is intact, individuals can respond to the

auditory stimulus, maintain their attention, and concentrate on their task for some time (Ghasemy et al., 2019).

According to Curtis et al. (2010), the Seashore Rhythm (Seashore) Test and the Speech-Sound Perception Test are two popular neuropsychological tests that measure auditory perception as a part of the Halstead-Reitan Neuropsychological Battery Test. Dodrill and Dikmen (1978) stated that the brief Seashore Test can be used to differentiate patients with neurodegenerative disease from healthy participants at a statistically significant level. The Seashore Test is a forced-choice response format test and contains 30 trials (Curtis et al., 2010). An examinee needs to determine if the two presented sounds are the same or have different patterns (Curtis et al., 2010).

Arroyo-Anllo et al. (2019) opined that AD may affect several musical competences in patients, suggesting that AD represents the "aphaso-agnosoapractic-amusia syndrome" (p. 9). According to Arroyo-Anllo et al., AD causes impairments in tone recognition, pitch perception, tonal working memory, timbre, and rhythm. Researchers have reported that patients with AD have partial ability to detect pitch, timbre, and rhythm (Arroyo-Anllo et al., 2019). Arroyo-Anllo et al. showed that patients with AD scored significantly lower in all music competence tests except for musical emotion recognition, compared to a control group. In patients with AD, the Seashore Test documented their worst performances (Arroyo-Anllo et al., 2019). Thus, Arroyo-Anllo et al. stated that musical processing weakness is a pervasive issue in patients with AD. There is a connection between the Seashore Test and emotional prosody recognition and emotional learning, which emphasizes the effect of psychological aspects of AD on musical ability (Arroyo-Anllo et al., 2019).

Soble et al. (2019) described logical memory (LM) as a subtest of the WMS-IV, which measures auditory-verbal contextual learning and memory with excellent reliability and validity. For this test, the individual listens to two short stories one at the time (in older adults ages 65 or older, the first story is presented twice) (Soble et al., 2019). After hearing each story, the examinee should recall the story and verbalize it in detail, then remember the stories again after 20 to 30 minutes (Soble et al., 2019).

The Verbal Paired Associates I and II are used to assess memory for associated word pairs (Indrani et al., 2015). This test has a list of 10-word pairs that the examiner reads to the examinee. Then, when the examiner reads the first word of each pair, the examinee is asked to give the associated word for each (Indrani et al., 2015). The examiner then asks the examinee to recall the paired words after 20 to 30 minutes without providing any feedback (Indrani et al., 2015). Logical memory (LM) and verbal paired associates can detect verbal or linguistic memory issues, which are language-based memory and one type of short-term memory. Linguistic memory is the ability to remember words and verbal items for a short time (Morey & Cowan, 2005).

The Digit Span Test is part of the WAIS-IV test to measure working memory. Baddeley (2012) stated that working memory (WM) is a cognitive process that stores and manipulates information in short-term memory. Auditory working memory (AWM) maintains sounds actively in mind for a short time after the sounds are not presented anymore (Kumar et al., n.d.). According to Webber and Soble (2018), Digit Span (WAIS-IV) (Wechsler, 2008) is one of the oldest and most reliable and valid tests. The Digit Span subtests include Forward for assessing short-term memory, backward for assessing

recall tasks, and a digit sequencing task for evaluating working memory (Lumpkin & Sheerin, 2019).

Johnson and Chow (2015) stated that multiple brain and cognitive processes are necessary to create a hearing sensation. Changes in this process could be one of the preclinical signs of AD or other neurodegenerative diseases. Although changes in the hearing function is not a significant concern for these patients, changes in the processing of sounds could be one preclinical piece of information and one of the first detectable preclinical signs to diagnose AD (Johnson & Chow, 2015). Patients who have dementia might have difficulty comprehending speech or finding words during conversations, but the severity of this difficulty depends on the type and stage of their neurodegenerative diseases (Johnson & Chow, 2015). Other patients might have a challenge with following multiple auditory orders or complicated instructions (Johnson & Chow, 2015). Johnson and Chow suggested that music information processing in patients with dementia could be different from those who do not have dementia since the central auditory system is usually impaired in patients with neurodegenerative disease. Adults who have hearing loss develop Alzheimer's or other types of dementia more often than others do. Also, patients with Parkinson's disease have a higher chance of high-frequency sensorineural hearing loss than other healthy adults, even though they are unaware of it (Johnson & Chow, 2015).

Because patients with dementia usually do not complain about their hearing loss, examining their hearing function is highly recommended. In patients with neurodegenerative problems, central auditory system impairment is common (Johnson & Chow, 2015). Grahn and Brett (as cited in Johnson & Chow, 2015) conducted a study

with 15 patients who had Parkinson's disease and studied the rhythm recognition tasks completed by these patients. Grahn and Brett realized that these patients had difficulty identifying the beat structure, compared to the control group, but did not have any difficulty perceiving non-beat conditions. Human speech can be affected by different types of dementia. In the case of patients with AD, anomia or difficulty in word-finding is evident. These patients have a hard time accessing semantic information, which leads to general semantic deterioration (Johnson & Chow, 2015).

Diekfuss et al. (2018) stated that the concern of adults in America about AD is second only to cancer. According to this study, dementia is classified as a variety of neurocognitive disorders, including "AD, frontotemporal lobar degeneration, Lewy body disease, vascular disease, traumatic brain injury, substance/medication use, HIV infection, prion disease, Parkinson's disease, Huntington's disease, another medical condition, multiple etiologies, or unspecified" (p. 150). Fritsch et al. (2019) estimated that more than 131 million individuals will have AD in the world by 2050 (AD comprises an estimated 60% of all dementias).

When clinicians diagnose individuals with AD before they develop Alzheimer's dementia, they help to prevent or delay the development of dementia by educating patients and their families about the risk of being exposed to the common risk factors (Rasmussen & Langerman, 2019). Even though clinicians cannot reverse any existing pathological changes, early diagnosis of AD will give patients and their caregivers a chance to plan for the future and allow them to benefit from available treatments that help manage the symptoms (Rasmussen & Langerman, 2019). It is essential to recognize these individuals at the earlier stages, give them the chance to benefit from early intervention,

and preserve their functions for a longer time. Early diagnosis and intervention will lead to delaying the onset of dementia, which benefits the patients and their families and will help reduce the cost in healthcare fields (Rasmussen & Langerman, 2019).

The number of AD patients is escalating globally, and there is an urgent need to diagnose these individuals and prevent or delay disease onset (Rasmussen & Langerman, 2019). Even though there are some standard and practical cognitive tests to diagnose AD, this study investigates if adding three quick and simple tests such as the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), and the Seashore Rhythm (Seashore) Test (Seashore, 1915) to the standard memory tests such as Logical Memory (WMS-IV) (Wechsler, 2009), Verbal Paired Associates (WMS-IV) (Wechsler, 2009), and Digit Span (WAIS-IV) (Wechsler, 2008) can help clinicians to detect neurodegenerative diseases at earlier stages.

Problem Statement

Knickman and Snell (2002) believed that the number of individuals aged 66 to 84 will be 61 million people in 2030. This number will be 9 million people more when we also consider individuals who will be above 84 years old. Considering that 40% of these individuals might have some degree of memory impairment (Small, 2002), researchers need to expand their work and look for different tools to facilitate AD and dementia diagnosis. Researchers have conducted several studies showing the relationships among the Seashore, the Speech-Sound Perception Test, and the SCAN-A tests on memory impairment (Al-Hameed et al., 2019; Carl & Sureyya, 1978; Gates et al., 2008; Johnson & Chow, 2015; Rodríguez-Aranda et al., 2016; Tsoi et al., 2019; Wankerl et al., 2017). However, they have not yet investigated whether performing a combination of these tests

could be an effective way to facilitate diagnosing memory impairment in individuals with neurodegenerative disease. This study attempted to look at this question.

Purpose of the Study

The purpose of this quantitative study was to examine if tests of auditory working memory (WAIS-IV Digit Span; Wechsler, 2008), tests of sustained auditory attention (SCAN-A; Keith, 1994), Speech-Sound Perception Test (Reitan & Wolfson, 1985), the Seashore Rhythm (Seashore) Test (Seashore, 1915), and tests of linguistic memory (Logical Memory, Verbal Paired Associates; Wechsler, 2009) discriminate between patients diagnosed with Alzheimer's disease and other patients undergoing psychological evaluation. The presence of AD was the dependent variable, and the independent variables were the scores from the measures of digital span (forward, backward, and sequencing) (Wechsler, 2008), SCAN-A (Keith, 1994), Seashore (Seashore, 1915), Speech-Sound Perception Test (Reitan & Wolfson, 1985), as well as Logical Memory and Verbal Paired Associates on the WMS-IV (Wechsler, 2009).

Research Questions and Hypotheses

For this study, I used archival data, which were collected from 2015 to 2021 by a private consulting psychology practice.

Research Question 1

Do the SCAN-A test scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H1_0$: SCAN-A test scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H1_a$: SCAN-A scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

Research Question 2

Do the Speech-Sound Perception Test scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H2_0$: Speech-Sound Perception Test scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H2_a$: Speech-Sound Perception Test scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

Research Question 3

Do the Seashore Test scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H3_0$: Seashore Test scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H3_a$: Seashore Test scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

Research Question 4

Do the WMS-IV Logical Memory scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H4_0$: WMS-IV Logical Memory scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H4_a$: WMS-IV Logical Memory scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

Research Question 5

Do the WMS-IV Verbal Paired Associates scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H5_0$: WMS-IV Verbal Paired Associates scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H5_a$: WMS-IV Verbal Paired Associates scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

Research Question 6

Do the WAIS-IV Digit Span scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H6_0$: WAIS-IV Digit Span scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H6_a$: WAIS-IV Digit Span scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

Theoretical Framework

According to Ciaramelli et al. (2013), theory of mind (ToM) is the human ability to understand one's own and other individuals' mental status in terms of thoughts, emotions, beliefs, intentions, and knowledge. This theory is about the ability to think about thinking and understand the differences between thoughts. When individuals come to know of other people's life experiences, this knowledge stimulates their feeling in a

similar condition (Ciaramelli et al., 2013). De Lucena et al. (2020) explained that ToM has two components: cognitive and affective. Cognitive ToM is the ability to understand cognitive states, while affective ToM is the ability to understand other individuals' emotions and feelings. Each of these components involves different neuronal systems. Shamay-Tsoory et al. (as cited in De Lucena et al., 2020) believed that adult individuals who have ToM affective impairment may show ventromedial prefrontal cortex (vmPFC) damage. ToM deficit may explain some of the behavioral abnormalities in patients with dementia. Le Bouc et al. (2012) showed the deficiency in two components of ToM in patients with AD and patients with frontotemporal dementia, while Ciaramelli et al. showed a link between ToM and episodic memory problems. Individuals need an intact ToM to have healthy social interactions, and any deficit may cause abnormal interpersonal behaviors, which is one characteristics of frontotemporal dementia (Le Bouc et al., 2012).

De Lucena et al. (2020) suggested that self-perspective inhibition is related to the cognitive process. That is, any effect in the metabolism of the left temporoparietal junction or the right lateral prefrontal cortex causes difficulty for an individual to infer someone else's beliefs. De Lucena et al. stated that the clinical and imaging evidences in their study were sign for deficits in two components of ToM in AD and patients with frontotemporal dementia.

Marschark et al. (2019) assessed ToM in three groups of younger individuals (hearing children, deaf children who had hearing parents, and deaf children who had deaf parents). They realized that children with deaf parents and hearing children had similar

ToM timetables, whereas children with hearing parents showed severe delays. This research highlighted the importance of hearing and having conversations to develop ToM or any ToM delays (Marschark et al., 2019). ToM helped me develop this study because it shows the importance of auditory perception in individuals' judgment and memory. It associates with prefrontal cortex damage and focuses on the working memory.

Nature of the Study

This is a quantitative non-experimental design study to examine if adding the SCAN-A (Keith, 1994), Seashore, and Speech-Sound Perception Test to the Logical Memory (WMS-IV), Verbal Paired Associates (WMS-IV), and Digit Span (WAIS-IV) can improve ability in diagnosing memory loss in patients with neurodegenerative disease. I used the previously validated and reliable assessment tools SCAN-A (Keith, 1994); Seashore (Dodrill & Dikmen, 1978); Speech-Sound Perception Test (Curtis et al. 2010); Logical Memory (WMS-IV) (Soble et al., 2019); Verbal Paired Associates (WMS-IV) (Indrani et al., 2015); and Digit Span (WAIS-IV) (Webber & Soble, 2018) to study possible improvement in ability of diagnosing memory loss.

The target population in this research was individuals who were 30 years old or older who were referred to the neuropsychological private practice located in Los Angeles County for neuropsychological evaluation by clinicians.

Definitions

The following definitions were used throughout the study:

Auditory working memory (AWM): The process which can maintain the sounds actively in individuals' minds for a short time after the sounds are not presented anymore (Kumar et al., n.d.).

Cognitive deficit: Decreasing functional problem-solving skills based on standardized assessment tool measurement (Rath et al., 2011).

Dementia: Declining memory and at least one other cognitive function such as language or decision-making function persistently to the point that this loss of intellectual abilities could interfere with an individual's daily activities (APA, 2020).

Functional memory disorder (FMD): The process of constantly worrying about losing memory without any objective evidence of cognitive impairment (Alexander et al., 2019).

Linguistic memory: The process of remembering words and verbal items for a short time (Morey & Cowan, 2005).

Long-Term memory (LTM): This process is associated with the maintenance of information to retrieval in the future (APA, 2020).

Short-Term memory (STM): STM is the process of recalling, recognizing, and reproducing a limited amount of material after 10 to 30 seconds (APA, 2020).

Sustained auditory attention: The process of responding to the auditory stimulus, maintaining the attention, concentrating on the task for some time (Ghasemy et al., 2019).

Working memory: The process of restoring memory to accomplish tasks. This is a cognitive process, which consists of the central executive, phonological loop, and visuospatial sketchpad (APA, 2020).

Assumptions

My first assumption was that study participants were motivated to perform sufficiently during the administration of this study's cognitive tests. My second assumption was that Logical Memory (WMS-IV) (Wechsler, 2009), Verbal Paired Associates (WMS-IV) (Wechsler, 2009), and Digit Span (WAIS-IV) (Wechsler, 2008) assess neurodegenerative diseases (AD) accurately. Another assumption was that the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), and the Seashore Rhythm (Seashore) Test (Seashore, 1915) would be able to detect memory impairments in neurodegenerative diseases (AD) at the early stage of the disease. My other assumptions were that education, economic status, gender, and geographical information were not factors in this study. In this study, I assumed that study participants received the equivalent care. They tested in the same environments since all of them attended the same psychological clinic. All the cognitive tests were administered by licensed clinical psychologists or doctoral-level clinical psychology students trained to administer, score, and interpret these cognitive tests. All the test responses and interpretations were reviewed by a supervising licensed clinical psychologist and safely secured in the office.

Scope and Delimitations

My focus in this study was on individuals who were 30 years old or older who were referred for neuropsychological evaluation by clinicians in Los Angeles County and had records in the selected private consulting psychology practice from 2015 to 2021. This study population only included individuals who were 30 years old or older who were referred for neuropsychological evaluation by clinicians to this specific psychological

clinic. The results of this study might not be generalized to other populations who live in other parts of the country. Additionally, this study does not represent of the general population in terms of their age, gender, and ethnicity.

Limitations

In this study, I analyzed archival data from individuals referred to a neuropsychological practice located in Los Angeles County by their neurologists or general practitioners. Given that, a limitation that may apply to this study stems from using a purposive sample or judgmental sample. According to Elfil and Negida (2016), judgmental sampling occurs when researchers select their study participants by choice after assuming they have specific characteristics. Another significant limitation of this study is the geographical location of individuals who participated in this study. Since most of these individuals were from the South Bay area, the findings may not be generalizable beyond that specific geographical area.

Significance of the Study

According to the Los Angeles County Department of Public Health, Office of Health Assessment and Epidemiology (2008), there are 147,000 individuals with AD in Los Angeles County. It was suggested that the prevalence of AD among the general population would mean that 325,000 would develop AD sometimes during their lives. Fiorini et al. (2017) reported that dementia is a chronic disease that affects more than 35 million individuals worldwide and has caused disability in older individuals with a global societal cost of US$ 604 billion. In this study, I examined if performing the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), and the Seashore Rhythm (Seashore) Test (Seashore, 1915), along with the other diagnostic tools

such as Logical Memory (WMS-IV; Wechsler, 2009), Verbal Paired Associates (WMS-IV; Wechsler, 2009), and Digit Span (WAIS-IV; Wechsler, 2008) could facilitate diagnosing memory impairment in individuals with neurodegenerative disease in an earlier stage.

This study's results and findings might help clinicians diagnose neuro-degenerative disease patients who might not have access to more advanced tests. It benefits individuals who cannot afford the cost of amyloid Positron Emission Tomography or other expensive tests that can identify high-risk patients with progressive cognitive decline such as AD (Al-Hameed et al., 2019). This study emphasized that by spending a few more minutes administering three more cognitive tests besides the previous standard memory tests, practitioners could diagnose AD in an earlier stage of the disease with a much lower cost.

Positive social change will be enhanced by applying interventions in diagnosis neurodegenerative disease patients. This positive change can occur in many ways, such as saving a tremendous amount of money for the healthcare system by diagnosing AD patients using not costly tools. Early diagnosis of these patients can reduce their risk factors only by changing their lifestyle. It also can provide them with the proper medical interventions (Jayakody et al., 2020). Haider et al. (2020) stated that early detection of these patients and adequate intervention could prevent almost 35% of AD cases. Early diagnosing of AD gives patients and their caregivers a chance to plan for their future. It will allow them to access different available treatments that could manage AD symptoms (Rasmussen & Langerman, 2019). Therefore, I hope that the information derived from

this study will promote more help to clinicians to diagnose AD patients in the early stage and save extra money for our health system.

Summary

It has been established that as individuals age, vision, hearing, and cognitive impairments escalate and cause individuals to seek medical help (Pye et al., 2017). As Al-Hameed et al. (2019) reported, many of these individuals are concerned about their memories and visit their primary care doctors to get help. However, diagnosing neurodegenerative diseases such as AD could be challenging for clinicians due to minimal routine screening tests. Al-Hameed et al. (2019) explained that most cognitive impairment diagnostic tests are located in specific contexts and are very expensive. As a result, not all individuals have the option of using these diagnostic tests. Other cognitive tests such as Dementia-Detection (DemTect; Larner, 2007) and the Montreal Cognitive Assessment (MoCA; Sammer & Lenz, 2020) can only detect learning impairments with minimal validity and specificity (Al-Hameed et al., 2019, p. 2). Another available test to check memory impairment is the Logical Memory (WMS-IV; Wechsler, 2009). This test is excellent for studying short-term memory by checking individuals' linguistic memory (Morey & Cowan, 2005). As Morey and Cowan explained, linguistic memory is the ability to remembering verbal items. Two other reliable tests are available to check memory impairment: Verbal Paired Associates (WMS-IV; Wechsler, 2009) and Digit Span (WAIS-IV; Wechsler, 2008). Discovering alternate cognitive tests to detect memory impairment might help clinicians diagnose these patients more quickly with lower cost. It might also help these patients to benefit from the available treatment and help. This study

can promote social change agendas by introducing more available tools and cognitive tests for diagnosing AD patients in an early stage of their diseases.

Chapter 2 reviews the literature relating to auditory processing tests and AD and the effect of hearing impairment in AD patients. I also studied the importance of auditory processing tests in diagnosing AD and the relation between central auditory processing (CAP) impairment in patients with cognitive impairment. Additionally, the literature review explores the research on available cognitive tests for diagnosing neurodegenerative diseases and the validities and specificities of these tests. I made sure that the literature review addressed the research questions.

Chapter 2: Literature Review

Introduction

Cognitive, vision, and hearing impairments increase and reduce quality of life as individuals age (Pye et al., 2017). Studies have shown that these impairments are among the top 10 reasons why patients seek help and visit healthcare providers (Pye et al., 2017). In most neurodegenerative patients, the cognitive problem is a particularly significant concern. Most often, people with dementia, Parkinson's, and AD suffer from memory impairment (Rohrer et al., 2008). There are minimal routine screening tests to diagnose neurodegenerative disorders, and most of these tests are expensive, invasive, and only available in specific locations (Al-Hameed et al., 2019). Clinicians mostly use screening tests that have limited validity and specificity. These tests usually screen individuals' learning difficulties and cannot detect their functional memory disorders (FMD) (p. 2). Researchers believe early diagnosis of neurodegenerative diseases and receiving treatment as soon as possible can prevent progress of the disease (Johnson & Chow, 2015; Jones Lister et al., 2019). Researchers believe that hearing and vision problems are more common in individuals with dementia than in the general population (Pye et al., 2017). For the same reason, I investigated if performing the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), and the Seashore Rhythm Test (Seashore, 1915) as part of the auditory processing test, along with the Logical Memory Test, the Verbal Paired Associates Test (Wechsler, 2009), and the Digit Span (WAIS-IV) (Wechsler, 2008) can facilitate diagnosing memory impairment in individuals with neurodegenerative disease.

The purpose of this literature review was to focus on selected auditory tests such as the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), the Seashore Rhythm Test (Seashore, 1915), as well as the Logical Memory Test, and the Verbal Paired Associates Test (Wechsler, 2009), and the Digit Span (WAIS-IV) (Wechsler, 2008) and their results in individuals with AD. The literature review also focused on whether any of these tests have been used to diagnose individuals with neurodegenerative diseases in the past.

Literature Search Strategy

I used different search engines such as Walden Library databases, Google Scholar search, and Bing Search to gather the research for this study. I obtained the literature from EBSCO, PsycINFO, PsycARTICLES, and SAGE Journals in the Walden Online Library as well as Google Scholar. Key search terms for this study were neurodegenerative disease, Alzheimer's disease, Alzheimer, dementia, memory problem, memory loss, Dementia-Detection tools, the SCAN-A, the Speech-Sound Perception Test, the Seashore Rhythm Test, the Logical Memory Test, the Verbal Paired Associates Test, the Digit Span Test, hearing impairment, the Verbal Fluency Test, sustained auditory attention, and theory of mind. Older articles were used only as a theoretical foundation for this study.

Organization of the Review

Since not much literature is available for studying the effect of neurodegenerative disease on six different cognitive tests (the SCAN-A, the Speech-Sound Perception Test, the Seashore Rhythm Test, the Logical Memory Test, Digit Span, and the Verbal Paired Associates test) side by side, I organized the review of literature into six sections. Each

section has two components: AD and one of these six tests (SCAN-A, the Speech-Sound Perception Test, the Seashore Rhythm Test, the Logical Memory Test, Digit Span, or the Verbal Paired Associates Test).

The first subsection of the review of related research is AD and the SCAN-A test. In this subsection, existing current research dealing with AD and SCAN-A results was integrated. The second subsection includes current research on AD patients and Speech-Sound Perception test results. The third subsection focuses on articles and research on AD and the Seashore Rhythm results. The fourth subsection refers to AD and the Logical Memory test results, while the fifth subsection discusses AD and the Verbal Paired Associates test results. The final subsection discusses AD and the Digit Span test results.

Theoretical Foundation

Theory of Mind

One of the seminal theories associated with prefrontal cortex damage (De Lucena et al., 2020) that focuses on working memory is theory of mind (ToM). This theory shows the importance of auditory perception in judgment and memory. ToM has been studied for centuries, starting with a book by Hartley and Priestley (1775) who first presented this theory. Later in 1790, Priestley explained this theory in a more detailed format. As Ciaramelli et al. (2013) stated, ToM centers on how individuals understand their own and others' thoughts, emotions, beliefs, intentions, and knowledge. According to Kemp et al. (as cited in De Lucena et al., 2020), ToM has two parts: cognitive ToM and affective ToM. The cognitive part of ToM explains the ability to understand cognitive states, whereas the affective part refers to the ability to understand other individuals' emotions and feelings. The cognitive part of ToM involves the dorsolateral

prefrontal cortex (dlPFC), whereas the affective part involves the ventromedial prefrontal cortex (vmPFC) (De Lucena et al., 2020). There is a complex multisynaptic pathway between the hippocampal formation (HPF) and the prefrontal cortex (PFC). This complicated pathway is involved in cognitive functions and several other neuropsychiatric disorders (Sampath et al., 2017). It also involves regions that implicate depression, AD, and cognitive deficit problems (Sampath et al., 2017).

De Lucena et al. (2020) reported that ToM is impaired in patients with early-stage AD. In fact, when AD progresses, ToM will impair severely. On the other hand, Marschark et al. (2019) stated that "language, visual-spatial, and sequential processing abilities" have essential roles in assessing individuals' ToM (p. 111). Marschark et al. studied three groups of younger individuals (hearing, deaf, and deaf children who had hearing parents) and realized that children who were deaf but had hearing parents had severe delays in their ToM development, compared to children who were deaf and had deaf parents as well as hearing children. The researchers emphasized the crucial role of hearing and conversation in ToM development.

According to Baron-Cohen et al. (1997), AD patients do not have a "mind-reading" ability and cannot engage in conversations with others. Little (2003) agreed that ToM is a complicated cognitive task, and individuals who perform this task poorly have difficulty with their social interactions. Little also believed that individuals need to process different information and data that require healthy working memory to have an effective social interaction. As Gathercole and Pickering (2001) explained, working memory refers to individuals' mental workplaces in which they store temporary information and manipulate it during their social interactions (p. 88). ToM emphasizes

the importance of auditory perception in individual judgment and memory. It requires an entire prefrontal cortex area as well as an intact working memory. In their study, Perri et al. (2018) selected 20 AD patients to investigate the relationship between cognitive, emotional-affective, and auto-activation apathy and their performance with ToM. The researchers evaluated these patients' general cognitive domains and found significant correlations between ToM and Digit Span Backward scores (p. 16).

Bejanin et al. (2017) used structural MRI to study both affective and cognitive parts of ToM in 19 early- to moderate-stage semantic dementia patients who were diagnosed with primary progressive aphasia as well as 39 healthy individuals. Semantic dementia is a neurodegenerative disease that is identified by temporal lobe atrophy (Bejanin et al., 2017). This atrophy is bilateral but asymmetrical and usually involves the anterior part of patients' temporal lobes. Gradually, this atrophy affects the posterior and lateral temporal and frontal lobe structures (Bejanin et al., 2017). Patients' symptoms are related to the problematic areas of their brains. In the early stage of the disease, patients might have difficulty naming or understanding words (Bejanin et al., 2017). The researchers evaluated all study participants by performing cognitive tests such as working memory tests and other standard neuropsychological tests. As Bejanin et al. stated, some of these tests were Logical Memory and Verbal Episodic/Memory as part of the Wechsler Memory Scale (WMS) (Wechsler, 2008) subtest, as well as Digit Span (Forward and Backward) tests (Wechsler, 2008). After conducting an ANCOVA study, Bejanin et al. reported that the left medial temporal lobe damage caused difficulty in understanding other individuals' affective mental states. By contrast, impairment in the cognitive part of ToM was secondary to midline cortical structure damages (Bejanin et al., 2017). These

two brain networks and their connections play essential roles in patients' neuropathological processes and semantic dementia level (Bejanin et al., 2017).

In another study, Moreau et al. (2016) selected 20 patients with mild AD and 20 healthy individuals. Using a cross-sectional study, they proved a relationship between significant ToM impairment and the abnormal result of some cognitive tests, such as the logical memory of the WMS (Moreau et al., 2016). Because ToM is a complex task, impairment can occur even in the early stages of AD (Moreau et al., 2016). According to this theory, patients need to assume the belief of one person about other individuals' beliefs; they also need to understand the acerbity of bluffing and lying (Moreau et al., 2016). Moreau et al. used two tasks to assess study participants' ToM (standard false belief task and ecological task). In the typical false-belief task, individuals have to assume a character's belief, whereas the second task assesses the individual ToM in a natural situation that resembles daily interaction (Moreau et al., 2016).

Moreau et al. (2016) reported that AD patients have difficulty assuming other individuals' beliefs about reality. They also have trouble attributing information to a person during a conversation. Individuals need to have intact episodic memory to have functional ToM and to remember previous changes. As Moreau et al. reported, the self-projection mechanism is common to ToM and memory. This mechanism helps individuals project themselves into their past or into other individuals' minds. Moreau et al. believed that memory is essential for performing ToM if individuals interact with a person or experience similar situations. The researchers showed the relationship between ToM and memory by targeting the ability to remember the person who received the information from them and performed the tasks.

In summary, ToM relates to the present study because it focuses on the working memory, emphasizes the importance of auditory perception in an individual's judgment and memory, and similar to AD (Kulijewicz-Nawrot et al., 2012, p. 252) is associated with prefrontal cortex damage.

Conceptual Framework

Agrawal and Biswas (2015) stated that 5 million individuals have AD and 1 million have Parkinson's disease. They believe that earlier diagnosis of these neurodegenerative disorders is essential and gives patients a chance to receive early treatment to possibly prevent the disease's progress. Fiorini et al. (2017) reported that dementia is a chronic disease that affects more than 35 million individuals worldwide and has caused disability in older individuals with a global societal cost of US$ 604 billion. Al-Hameed et al. (2019) reported that earlier diagnosis and treatment might prevent irreversible changes in patients' brains. Dementia-Detection (DemTect; Larner, 2007) and the Montreal Cognitive Assessment (MoCA; Sammer & Lenz, 2020) are beneficial for diagnosing AD or mild cognitive impairment, but as Al-Hameed et al. (2019) pointed out, these tests have limited validities and specificity and they only screen learning effects, not FMD. For the same reason, noninvasive, reasonable, repeatable tests that might take a few minutes to administer could benefit these patients. Therefore, adding the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), and the Seashore Rhythm (Seashore) Test (Seashore, 1915) to other established neurodegenerative diseases diagnostic tools such as the Logical Memory Test (WMS-IV; Wechsler, 2009), the Verbal Paired Associates Test (WMS-IV; Wechsler, 2009), and the Digit Span Test (WAIS-IV; Wechsler, 2008) might help to diagnose these patients in the

earlier stages of their disease at a lower cost. As Johnson and Chow (2015) reported, since patients with AD have sound processing problems as one of their preclinical signs, Auditory Processing tests are valuable tools to add to the previous diagnostic toolbox.

Auditory Processing Tests and AD

Jayakody et al. (2020) conducted a study to understand the function of the central auditory system in AD patients. They reported more than 44 million patients who suffered from dementia and AD in 2017. The researchers predicted that this number would increase to 76 million over the next 30 years. Studies have shown that the neuropathological changes in AD patients start many years before their clinical symptoms. In fact, in many patients with AD, peripheral hearing impairment and central auditory processing (CAP) disorders can be observed years before they show AD symptoms (Jayakody et al., 2020). This gap gives clinicians the chance to detect and prevent this disease.

Sidiras et al. (2019) conducted a study to focus on children with auditory processing disorder and the interaction between the auditory process and cognition. Sidiras et al. identified a relationship between auditory attention and working memory, as well as nonverbal intelligence and psychoacoustic test performances (p. 2). Sidiras et al. believed that auditory processing disorder is an attention problem. In another study, Iliadou et al. (as cited in Sidiras et al., 2019) investigated the sensory aspect of auditory processing. Iliadou et al. reported that in older individuals, when mild cognitive impairment changes to Alzheimer's disease, temporal resolution in the left temporal cortex changes and becomes thinner; they emphasized the sensory aspect of auditory processing tests.

Researchers have investigated rhythm perception in children who had auditory processing disorder, compared with the control children. They found that the control children's performances were allied with their auditory attention, whereas this correlation did not exist in children with auditory processing disorders (Sidiras et al., 2019). According to Sidiras et al. (2019), poor rhythm perception in these children resulted from sensory processing deficits, not attention deficits. This study emphasized the relationship between rhythm and speech perception tests.

Hearing Impairment and AD

According to Jayakody et al. (2020), almost 9% of the population is at risk for mid-life hearing loss and increased risk of AD. The auditory system has two components: the peripheral hearing system and the central auditory pathway (Jayakody et al., 2020). To have normal communication skills, understand speech against background noises, and process language and receive information, individuals need to have an intact central auditory pathway, which includes the cochlear nucleus to the auditory cortex. Researchers have stated that damage to CAP skills plays an essential role in cognitive decline in AD patients, especially when they do not have any severe peripheral hearing loss. Jayakody et al. (2020) reported that individuals with severe CAP disorder are at higher risk for dementia. Studies have supported the connection between diminished central auditory functions and preclinical stages of AD (Jayakody et al., 2020). This link can help clinicians identify individuals who are at higher risk or at preclinical stages of AD (Jayakody et al., 2020).

Zheng et al. (2017) assessed the relationship between AD and hearing impairment by conducting a cohort study and searching existing library databases. In fact, they

combined four cohort studies, for a total of 7,461 participants. Three of these studies confirmed AD, and the fourth indicated mild cognitive impairment in the participants. Zheng et al. reported that the risk of individuals with hearing problems developing AD compared with the control group was 4.87. After combining all four studies and considering AD and mild cognitive impairment as cognitive disorders that incorporate this relative risk, the researchers reported a significant difference (2.82); hearing impairment increases the chance of cognitive disorders. Almost 50-80% of elderly individuals (more than 80) have a hearing impairment. Since AD and hearing impairment are both age-related issues, researchers have studied the association between these two medical problems for many years, but Zheng et al. believed that the relationship between hearing impairment and AD is still unclear, despite the research. Most studies have focused on peripheral hearing dysfunction, but the association between CAP and cognitive decline has not received enough attention.

Kamourieh et al. (2018) conducted a study with 22 healthy individuals, 31 individuals who complained of memory loss, and 21 patients with AD. They let these participants hear a speaker talking in distracting backgrounds or alone without any distractive noises, and then asked if they registered the target speech. The researchers used MRIs to check brain activities. The results indicated that patients with low speech registration performances had more cognitive impairments (Kamourieh et al., 2018). Also, speech registration was related to auditory cortex and multiple-demand brain region activities (Kamourieh et al., 2018). When individuals tried to separate target speech from background speech, multiple brain regions were active. At the same time, the midline and lateral frontal cortex showed lower activities (Kamourieh et al., 2018). According to

Kamourieh et al., a central cholinesterase inhibitor in half the patients was at a low level and could not increase brain acetylcholine levels and improve patients' task performances. Acetylcholine regulates the attentional system, but in AD patients, the level of modulatory monoaminergic neurotransmitter diminishes (Kamourieh et al., 2018). Even though using this neurotransmitter in patients with AD improves their attentive registration in their conversations, various side effects prohibit using this neurotransmitter (Kamourieh et al., 2018). These researchers performed a second MRI 6-11 weeks later and found that individuals' performances changed because of right hemisphere frontotemporal system activity changes. This brain area is an essential part of sustained auditory attention (Kamourieh et al., 2018). In AD patients, medial temporal lobe dysfunction is an early pathology effect (Kamourieh et al., 2018). When AD patients are in the pre-symptomatic stage of their disease, the entire neocortex is involved (Kamourieh et al., 2018). In these patients, episodic memory impairment could be followed by other cognitive deficiencies, attention problems, and difficulty in making decisions. These changes can be seen in other neurodegenerative diseases such as Lewy body disease or depression (Kamourieh et al., 2018). Because of poor attention, AD patients cannot register or recollect what a speaker says to them (Kamourieh et al., 2018). Patients believe that their memory during their social functions is more unsatisfactory than when they have a conversation in a quiet situation. In AD patients who have signs and symptoms of AD such as memory impairment, the limbic and paralimbic structures are already involved and show the necrotic area in their brains (Kamourieh et al., 2018). For the same reason, an early neuropsychological evaluation is necessary.

Jones Lister et al. (2019) believed that diagnosing AD patients in the earlier stages of their disease can delay or prevent their transition to the worse disease phase. Signs and symptoms of mild cognitive impairments might present years before an individual meets the criteria for AD. According to Jones Lister et al., detecting pure-tone hearing loss in these individuals is not a useful marker for diagnosing these patients' cognitive impairments, whereas "The amplitude of the auditory event-related potential that appears approximately 200 ms after a sound onset" is considered a better diagnostic indicator (p. 22). Jones Lister et al. stated that the Dichotic Sentence Identification (DSI) Test is one of the most sensitive auditory processing measuring tests available to detect mild cognitive impairment (MCI). They believed that individuals with MCI have a problem processing competing speech information (Jones Lister et al., 2019). At the same time, Haider et al. (2020) conducted a study to focus on diagnosing AD by using acoustic information from individuals' speech. They noticed that most patients with AD have difficulty with word finding, which might lead to vagueness. Speech and language are global sources of cognitive-behavioral data (Haider et al., 2020).

Indeed, auditory processing tests are not new tools in the medical field, and researchers have used them for more than 50 years. Bocca et al. (as cited in Fuente & McPherson, 2006) used filtered speech to study individuals with temporal lobe tumors in 1954. Also, Kimura studied cerebral lesions in patients using dichotic stimulation tests (Fuente & McPherson, 2006). Researchers have used some auditory processing tests to study AD patients. For example, Iliadou and Kaprinis (2003) stated that patients with AD might have difficulty understanding speech because of degeneration in the central auditory system, especially with background noises. In these individuals, perception and

processing of speech are affected. Iliadou and Kaprinis continued that CAP disorder has affected many patients with AD. This is a disorder that might be diagnosed in the early stages. Since hearing and speech are very connected in human function, these patients might produce speech processing and production problems. By contrast, central nervous system degeneration in AD patients might lead to speech deterioration.

According to Ranasinghe et al. (2019), AD patients suffer from abnormal "enhanced behavioral response to pitch perturbation" (p. 1). These researchers used magnetoencephalographic imaging to show the correlation between the abnormal pitch perturbation response and the neural system in AD patients. They reported that in the early phase of perturbation, left prefrontal activity in AD patients decreases, whereas during the later perturbation stage, their right middle temporal activity increases. Ranasinghe et al. showed that the "speech-motor-control network" and "right temporal region" impairments could trigger an unusual sensorimotor response in AD patients. These abnormal neural integration mechanisms contribute to cortical network dysfunction and lead to behavioral and cognitive deficits in patients with AD (Ranasinghe et al., 2019). AD patients have insufficient left prefrontal cortex activity than other healthy older individuals, which might explain their cognitive deficits (Ranasinghe et al., 2019). Similarly, Häggström et al. (2018) conducted a study of 136 individuals and tested their peripheral and central hearing. They followed their participants for 5 years and found that a CAP disorder could lead to AD.

According to Ford et al. (2018), mid-life hearing loss could be the reason for 9.1% dementia cases worldwide. These researchers stated that the possibility of developing dementia in men with hearing loss was greater than for men without a

significant hearing problem. Ford et al. emphasized the role of hearing loss as a significant risk factor for dementia. In fact, hearing loss might lead to reducing the brain's volume in different areas, especially in the auditory cortex. Hearing loss might also accelerate an individual's brain atrophy in various areas such as the "superior, middle and inferior temporal gyri and parahippocampus" (p. 2). These brain areas are of greatest concern in individuals with AD.

To have an acceptable performance on the Verbal Paired Associates (VPA) Test, individuals need to have an intact medial temporal lobe and hippocampal formation (Pike et al., 2013). Patients with AD usually have neuronal loss and neurofibrillary tangles formation in the temporal lobe and hippocampal areas; thus, AD patients have difficulty performing the VPA (Pike et al., 2013). MRI studies with AD patients suggested medial temporal lobes atrophy as well as hypometabolism in the medial part of the temporal lobes. Pike et al. investigated the effectiveness of the VPA on diagnosing mild cognitive impairment patients. They selected 77 individuals with mild cognitive impairment and 77 healthy elderly individuals. Surprisingly, after conducting the VPA for both groups, the researchers realized that this test could not identify almost 70% of patients with mild cognitive impairment. They believe that clinicians should use different memory tests to diagnose individuals with cognitive impairment. They also emphasized patients' background history and reports of changes (Pike et al., 2013).

In another research study of cognitive impairment, Hemmy et al. (2020) reviewed 5,007 different studies and selected 57 that were unique with a low or medium risk of bias. In these studies, most of the participants were White and had a mean age of 73 years. These studies evaluated different cognitive tests such as clock-drawing tasks, the

Mini-Mental State Examination (MMSE; Tsoi et al., 2015), the Montreal Cognitive Assessment (MoCA; Sammer & Lenz, 2020), the Memory Impairment Screen (MIS), the Brief Alzheimer Screen, the Test Your Memory Test, the Minnesota Cognitive Acuity Screen, the 7-Minute Screen, and the Brief Memory and Executive Test (Hemmy et al., 2020). Of all these studies, 17 used memory tests to identify clinical Alzheimer-type dementia and 13 studied list-learning tasks. Other studies combined prose and figure recall (WMS), the Logical Memory prose recall task, the Fuld Object Memory Evaluation, and the Placing Test (p. 681). This study particularly emphasized the importance of memory tests in identifying AD patients.

Importance of Auditory Processing Tests

Clinicians have considered several factors in selecting different cognitive tests to evaluate their patients. These factors are time of administration, availability, cost of test, patient's tolerability, ease of scoring, and test sensitivity and specificity (Pye et al., 2017). According to Pye et al. (2017), clinicians have usually used the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), the MMSE (Tsoi et al., 2015), and Addenbrooke's Cognitive Examination (ACE-III; Hsieh et al., 2013) to assess their patients. These tests are easy, require less than 20 minutes to administer, and are available in several languages; moreover, they are safe to administer and can evaluate several cognitive components (Pye et al., 2017). All of these tests rely on an individual's auditory and visual perceptions. If the individual suffers from a sensory impairment, there is a chance for confounding the cognitive tests with this limitation, leading to a false-positive result for cognitive impairment. Since hearing impairment could go unrecognized in individuals who have been referred to the clinician for cognitive

evaluation, Auditory Processing tests can play a considerable role in facilitating AD and dementia diagnosis.

Of all these impairments, one of the earliest in patients with AD is the encoding and retrieval processing task, which results from medial temporal lobe (MTL) pathology (Lowndes et al., 2008). The Paired Associate Learning (PAL) or VPA test is one cognitive test that evaluates the MTL's function in these patients. Lowndes et al. (2008) reported that AD patients perform very poorly on this test. Although recognition tasks have reasonable specificity in AD patients, they are less sensitive compared to recall tasks. Individuals need to have good function for both recall and recognition processes to have an acceptable VPA performance (Lowndes et al., 2008). In this study, Lowndes et al. selected 22 AD patients in their early stage of the disease and 55 control elder individuals. Using the VPA test, the researchers found that the clinical value of this test was as a recognition tool. By conducting one brief test (the verbal PAL test), Lowndes et al. could assess the arbitrary and semantic parts of an individual's memory.

CAP Impairment and AD

Similarly, Jalaei et al. (2019) reported that MCI patients have a CAP impairment which affects their hearing performance; specifically, they have difficulty hearing, especially with background or competitive noise. These researchers concluded that CAP disorders in patients with MCI and AD occur more than in other populations. They selected 20 patients with MCI and 20 healthy individuals to assess their speech perception abilities with the Speech Perception in Noise (SPIN) and the Gap in Noise (GIN) tests. Jalaei et al. realized that understanding speech in a quiet environment was the same for all of their participants. By contrast, individuals with MCI had much more

difficulty understanding speech signals in noisy environments than healthy individuals. As a result, CAP tests should be one of the clinicians' tools to identify individuals with cognitive impairments. Patients with CAP impairments might develop a more advanced cognitive disease. They can lose communication ability with their caregivers and become isolated from others, putting them at a higher chance for AD (Jalaei et al., 2019). These researchers also stated that central auditory tests are sensitive to diagnosing cognitive impairments and can help identify the early stage of cognitive problems. This research has shown that almost half of patients with CAP impairments develop AD within 5-7 years (p. 87).

In addition, clinicians have assessed pre-symptomatic disease progression in individuals at risk for AD. These interventions included a cerebrospinal fluid (CSF) biochemical, imaging analyses, and cognitive testing. They also examined their patients' CAP by checking their comprehension of auditory stimuli in a noisy background (Tuwaig et al., 2017). Tuwaig et al. (2017) reported that CAP deficits in elder asymptomatic individuals could be indicators of pre-symptomatic AD. To show the importance of the auditory deficit role in mental disorders, Iliadou and Iakovides (2003) reported that by searching the 'auditory deficits' and 'mental disorders' keywords in the U.S. National Library of Medicine, they found more than 564 scholarly papers. This number was reduced to 79 papers when they used 'CAP Disorders' for 30 papers, replacing 'auditory deficits' to 'Alzheimer's disease' (Iliadou & Iakovides, 2003). Psychoacoustic and electrophysiologic testing are available tools to assess the Central Auditory System. As a result, psychologists, neurologists, neuropsychologists, and audiologists should have close cooperation.

AD patients usually show CAP dysfunction with satisfactory peripheral auditory function (Gates et al., 2008). Individuals with CAP dysfunction can generally hear in a quiet environment, whereas they have difficulty hearing in noisy and difficult listening areas (Gates et al., 2008). In other words, people with CAP dysfunction cannot easily hear a single conversation between competing conversations. When people age, the prevalence of CAP dysfunction increases. Aging, dementia, medical issues such as stroke, neoplasm, or head injury, and developmental problems are common causes of CAP dysfunction (Gates et al., 2008). According to Gates et al. (2008), even in the early stage of memory loss, such individuals show some difficulty with their central auditory functions. Gates et al. suggested that clinicians use imaging and cognitive screening to diagnose AD in the early stage of the disease to delay its progress. Thus, individuals with memory problems even without AD might have abnormal results in their central auditory tests (Gates et al., 2008). Considering that almost half of these older individuals might show AD shortly, early diagnosis could benefit them tremendously (Gates et al., 2008).

Putcha et al. (2019) conducted a study to investigate brain behavior when administering neuropsychological tests (verbal episodic memory). This study was based on 235 individuals' brain cortical network contributions to their performances, all of whom had mild cognitive impairment. These researchers studied the most common networks in the brain which are usually impacted in AD as well as the effect of hippocampal atrophy on memory impairment (Putcha et al., 2019). The results indicated that individual performances on initial trials were linked to "attention regulation and strategic encoding efforts," whereas long-term memories related to the hippocampus (p. 89). Delayed Recall memories are supported by hippocampus volume and

frontoparietal thickness and function. By contrast, retention depends only on hippocampus volume and function (Putcha et al., 2019).

Daily Instrumental Activities

Karzmark and Deutsch (2018) believed that neuropsychological tests have an essential role in predicting individuals' instrumental activities of daily living. They stated that studies concerning instrumental activities of daily living have been limited to brief and repeated batteries. Thus, using cognitive tests to predict individuals' instrumental activities of daily living is very meaningful. To this effect, Karzmark and Deutsch selected 117 adult individuals referred to a university medical department for a neuropsychological evaluation. Their mean age was 47.9, and their medical problems were multiple sclerosis, CVA (cerebrovascular accident), brain injury, dementia, a developmental issue, psychiatric diagnosis, tumor, and other neurologic diseases. After excluding the unqualified patients from their study, Karzmark and Deutsch conducted different cognitive tests such as the Halstead Reitan Battery (HRB; Sweeney, 1999) and some part of the Wechsler Adult Intelligence Scale (WAIS)-III (Wechsler, 1997). They also asked individuals who lived independently to complete the instrumental activities of daily living questionnaire. If patients lived with caregivers, the caregivers completed the Functional Activities Questionnaire. Karzmark and Deutsch reported that a complete neuropsychological assessment can increase the clinicians' abilities to predict patients' capacity for their instrumental activities of daily living. They believed that a brief assessment has mild predictive accuracy concerning individuals' performance for instrumental activities of daily living (Karzmark & Deutsch, 2018).

Karzmark and Deutsch (2018) used sensitive and specific tests since these are two important factors to measure test validity. Sensitivity shows if the test can classify sick individuals, whereas specificity refers to the test's capability to classify healthy individuals (Karzmark & Deutsch, 2018). The percentage of patients who have positive test results is a positive predictive value. By contrast, the percentage of patients who do not have positive test results is the negative predictive value (Karzmark & Deutsch, 2018). After checking for sensitivity, specificity, and negative and positive predictive values, Karzmark and Deutsch-reported that a comprehensive test battery moderately improves predictive accuracy in older people and provides better accuracy to predict capability for instrumental activities of daily living.

Conclusion

According to Jayakody et al. (2020), early diagnosis of AD can prevent or delay the patients' condition by reducing risk factors, changing lifestyle, and providing medical intervention. Moreover, early detection and intervention may prevent almost 35% of AD cases. Several linguistic tests, as part of a cognitive assessment, can help to diagnose AD (Haider et al., 2020). Each of these neuropsychological tests proposes small insights into diagnosing AD in the early stages. Still, other alternative methods that could help to diagnose AD in the early stages will benefit patients (Haider et al., 2020). Therefore, the current study postulated the benefit of conducting tests of auditory working memory Digit Span (WAIS-IV) (Wechsler, 2008), tests of sustained auditory attention (SCAN-A; Keith, 1994), Speech-Sound Perception Test (Reitan & Wolfson, 1985), Seashore Rhythm Test (Seashore, 1915), and tests of linguistic memory (Logical Memory, Verbal

Paired Associates; Wechsler, 2009) in discrimination between patients diagnosed with AD and other patients undergoing psychological evaluation.

Chapter 3: Research Method

Introduction

The purpose of this quantitative correlational study was to examine if performing the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), and the Seashore Rhythm (Seashore) Test (Seashore, 1915), along with the other diagnostic tools such as Logical Memory (WMS-IV; Wechsler, 2009), Verbal Paired Associates (WMS-IV; Wechsler, 2009), and Digit Span (WAIS-IV; Wechsler, 2008) could increase the predictability of diagnosis of neurodegenerative diseases at the early stage of those diseases. I discuss the research design in this chapter as well as the methodology and the study population, sample size, and rationale for sample size, sampling procedures, data collection, and analysis. I also restate the research questions and review quantitative research design in more detail. I conclude with a summary of important points of the chapter.

Research Design and Approach

I used a quantitative method for this study. Quantitative methods have been described as a research methodology that requires the use of mathematical techniques to provide statistical inferences about the relationships or differences on numerically measured variables (Camm, 2012; Hancock & Mueller, 2010; Wisniewski, 2016). Quantitative methodology is normally used on studies that have research questions pertaining to “who,” “what,” and “how many” (Leavy, 2017).

To answer the research questions, I used a correlational research design. Correlational research designs seek to determine relationships between numerically measured variables (Curtis et al., 2010; Goodwin & Goodwin, 2013). The use of

correlational research design provides opportunity to evaluate both the magnitude and behavior of the relationships between variables (Leedy & Ormrod, 2012; Whitley et al., 2013). Through the use of the quantitative method with correlational research design, insights on how the results from the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), the Seashore Rhythm (Seashore) Test (Seashore, 1915), the Logical Memory (WMS-IV; Wechsler, 2009), Verbal Paired Associates (WMS-IV; Wechsler, 2009), and Digit Span (WAIS-IV; Wechsler, 2008) (predictor variables) predict the diagnosis of neurodegenerative diseases (criterion variable) through logistic regression analysis, which helped address the research questions and hypotheses of this study.

Other research designs such as causal-comparative and experimental were deemed to be inappropriate for the study. A causal-comparative research design primarily aims to explain the differences of means of a dependent variable across two or more groups (Babbie, 2013; Rottman & Hastie, 2014). I focused on only one group of participants (i.e., patients) and did not differentiate among other groups. An experimental approach was also not appropriate for this study as it uses a hypothesis (or several hypotheses) that affirms whether a treatment or an experiment affects a variable or variables (Babbie, 2013; Hoe & Hoare, 2012). I did not conduct any treatment or experiment on any participant or patient and only focused on their existing characteristics. Causal-comparative and experimental research designs were therefore considered inappropriate for the objective of this study.

Methodology

Population

The target population for this study was adult individuals with memory problems who were referred by their neurologists or general practitioners for testing and diagnosis of their memory impairment. The population of interest was adult individuals with memory problems in Los Angeles County and had records in the selected private consulting psychology practice from 2015 to 2021. The Los Angeles County Department of Public Health, Office of Health Assessment and Epidemiology (2008) reported 147,000 individuals with AD in Los Angeles County. This report indicated that prevalence of

AD suggested that 325,000 would develop AD sometimes during their lives.

Sampling and Sampling Procedures

I used a sample from the existing database that was available to me. Convenience sampling allows a researcher to identify the sample for the study from a part of the target population that is close to hand. Convenience sampling is a type of nonprobability sampling in which people are sampled simply because they are “convenient” sources of data for researchers (Creswell, 2012). Convenience sampling is a sampling technique for qualitative and quantitative studies, even though it is more used in quantitative studies (Suen et al., 2014). In this technique, the researcher uses accessible data (Suen et al., 2014). According to Bujang et al. (2012), convenience sampling is done on a first-come, first-serve basis, according to the same concept; Bujang et al. believed that convenience sampling and systematic sampling are comparable. The convenience sampling

methodology was consistent with the sample frame of this study, which was only to consider cases involving adult individuals with memory problems. The inclusion criteria for this study were: (a) cases involving patients from 30 to 95 years old; (b) referral for neuropsychological evaluation by licensed clinicians; (c) administration of a complete battery of neuropsychological tests; and (d) living in the United States. The exclusion criteria were: (a) cases involving patients under 30 years old, and (b) had not completed the neuropsychological tests (i.e., SCAN-A, the Speech-Sound Perception Test, Seashore Test, Logical Memory Test, Verbal Paired Associates Test, and WAIS-IV Digit Span).

The required sample size was determined by conducting a power analysis using G*Power software (Faul et al., 2013). Four factors considered in the power analysis were significance level, effect size, power of test, and statistical test. Significance level refers to the probability of rejecting a true null hypothesis, also commonly called a Type I error (Haas, 2012). On the other hand, the power of test refers to the probability of rejecting a false null hypothesis (Haas, 2012). In most quantitative studies, significance level is set at 95% and power of test is set at 80% (Koran, 2016). I used the same factors for this study: 95% significance level and 80% power of test. The effect size indicates the estimated degree of relationship between predictor and criterion variables (Cohen, 1988). Effect size is normally categorized into small, medium, and large; medium effect size is commonly used for quantitative studies as it strikes a balance between being too strict and lenient in estimating the degree of relationship between the variables (Berger et al., 2013). Lastly, I used logistic regression analysis to address the research questions and test the hypotheses. Given 95% significance level, 80% power of test, medium effect size (f^2 = .15), and logistic regression analysis with one predictor at a time, the minimum

required sample size was 55. However, given the available data for analysis, I included and analyzed 150 cases instead.

Procedures for Recruitment, Participation, and Data Collection

Before any data collection began, I secured Institutional Review Board (IRB) approval. Once IRB approval from Walden University was obtained, I followed all approval conditions and conducted the data collection plan as follows.

I accessed archival data from the database collected during the past 6 years (from 2015 to 2021) in a private consulting psychology practice to conduct this research. Permission to gather data from the records of the selected private consulting psychology practice from 2015-2021 was secured. All the neuropsychological tests were administered by licensed clinical psychologists or by doctoral-level clinical psychology students who were trained to administer, score, and interpret these cognitive tests. If the testing was administered by a trainee, the results were reviewed by a supervising licensed clinical psychologist. Cases selected for inclusion in the study were individuals who were 30 years old or older who were referred for neuropsychological evaluation by clinicians. They all were individuals who signed a consent form to allow their data to be used in research. Only individuals who were administered a complete battery of neuropsychological tests were included in the data for analysis. Demographic data including age, gender, and education were also collected to describe the sample and determine generalizability. Individuals who were under 30 years, could not speak fluent English, or did not complete all the tests including the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), the Seashore Rhythm Test (Seashore, 1915), the Logical Memory Test, the Verbal Paired Associates Test

(Wechsler, 2009), and the Digit Span (WAIS-IV) (Wechsler, 2008) were excluded from this study.

Instrumentation and Operationalization of Constructs

Data from six instruments were used for this study. These six instruments were SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), the Seashore Rhythm (Seashore) Test (Seashore, 1915), the Logical Memory (WMS-IV; Wechsler, 2009), Verbal Paired Associates (WMS-IV; Wechsler, 2009), and Digit Span (WAIS-IV; Wechsler, 2008). The description, reliability, and validity information for each instrument are discussed below.

SCAN-A

SCAN-A is a useful test to detect auditory processing issues in adolescents and adults with normal auditory thresholds (Keith, 1994). SCAN-A is an easy and quick test to administer, taking only 20 minutes to complete. SCAN-A has four different subtests: Filtered Words subtest, Auditory Figure-Ground subtest, Competing Words subtest, and Competing Sentences subtest (Lovett & Johnson, 2011). For the Filtered Words subtest, the examinee repeats presented words. These words are low-pass filtered words. The test takers hear half of the words in their right ear and the other half in their left ear. In the Auditory Figure-Ground subtest, the examinee repeats presented words while hearing background noise that is not clear and includes babble. Then, in the Competing Words subtest of this test, the examinee is asked to repeat both words presented to the ear. In last part of this test and in the Competing Sentences subtest, the examinee needs to repeat one of the sentences heard in the left or right ear while it is presented dichotically (Lovett & Johnson, 2011). Keith (1994) reported that the SCAN-A has a test-retest reliability

coefficient of .69 and an overall Cronbach's alpha of .77, which indicates that the SCAN-A has good internal consistency and is dependable across repeated administrations of the survey. Furthermore, Keith assessed the concurrent validity of the SCAN-A using 29 subjects by comparing performances on the first three SCAN-A subtests with corresponding subtests and the composite total score of the SCAN. The results showed there was a need to revise some word pairs that had negative correlations with the total score. After corrections, the composite standard score on SCAN was .59.

Speech-Sound Perception Test

This test has 60 words that contain the "ee" sound in the middle. These words do not have any meanings. The examinee hears these words from a tape recorder and needs to choose the correct responses from four different options (Reitan & Wolfson, 1985).

Seashore Rhythm (Seashore) Test

The Seashore Rhythm (Seashore) Test is designed to measure individuals' auditory perceptions. This test has 30 pairs of rhythmic beats, and the examinee needs to determine if the pattern of two presented sounds is the same or different (Curtis et al., 2010). The examiner calculates the raw score which corresponds with the correct answers. Ross et al. (2006) reported "adequate internal consistency, with split-half reliability coefficients ranging from 74 to .87" (p. 803).

WMS-IV Logical Memory

According to Soble et al. (2019), Logical Memory is one of the WMS-IV subtests which has excellent validity and reliability. This test measures the auditory-verbal contextual learning and memory (Soble et al., 2019). After hearing two short stories one at the time, the examinee should thoroughly recall and verbalize the story to the

examiner. If the examinee is 65 or older, the examiner repeats the first story for a second time. After 20 to 30 minutes, the examinee should verbalize the stories again (Soble et al., 2019). The Logical Memory is a good test for measuring short-term memory by detecting individuals' linguistic memory (Morey & Cowan, 2005). According to Morey and Cowan, linguistic memory is the ability to remember words and verbal items.

WMS-IV Verbal Paired Associates

Pike et al. (2013) explained that the old version of the WMS-IV Verbal Paired Associates has a list of 10 paired words which individuals learn during four trials. The total number of remembered pairs with cueing plus the learning trials shows the test score. On the other hand, delayed recall is the number of pairs recalled with cueing after 20 minutes. Some of the paired words in the Verbal Paired Associates are easy and related to each other, such as sky and cloud, whereas some are hard and not related, such as hot and quiet. In 2009, Wechsler reported that researchers removed several subtests (such as Faces, Family Pictures, Word Lists, Letter-Number Sequencing, Digit Span, Spatial Span, Information and Orientation, and Mental Control), added new subtests, and modified other subtests (such as Logical Memory, Verbal Paired Associates, and Visual Reproduction) from WMS-III to facilitate scoring, administering, and time managing the WMS-IV. In the new version of the WMS-IV Verbal Paired Associates, number of word pairs, percentage of easy to hard pairs, and number of learning trials have changed. Clinicians consider total learning and delayed recall for pairs to score this test (Pike et al., 2013). All cases in this study received the new version of the WMS-IV Verbal Paired Associates.

Digit Span (WAIS-IV)

I used the Digit Span as one important memory detector, since the forward Digit Span can measure short-term memory function and immediate recall, whereas the backward Digit Span can assess working memory (Cleary et al., 2018). The Digits Forward task is the first task that the clinician administers. The Digits Backward and Sequencing is administered after that (Lumpkin & Sheerin, 2019). There are two trials for each span length. If individuals provide wrong answers for both trials in one span length, the examiner will stop the test (Lumpkin & Sheerin, 2019). After combining each span length, the clinician will convert the raw score into a scaled score. The clinician records the longest span length for each test condition to compare to the mean and standard deviation (Lumpkin & Sheerin, 2019).

Cleary et al. (2018) reported that this test can measure short-term memory, immediate recall, and working memory (using backward digit span). According to Tulsky et al. (2003), Wechsler combines the forward and backward digit span to check individual intelligence. Tulsky et al. believed that the first memory assessment battery, which was a combination of verbal and visual immediate recall, belonged to Wells and Martin in 1923. Spencer et al. (2013) emphasized that the digit span test, especially the Reliable Digit Span (RDS), is one of the most useful and efficient cognitive tests. RDS is the sum of the longest part of the forward and backward digit span (Greiffenstein et al., 1994, as cited in Spencer et al., 2013). Spencer et al. (2013) reported that the RDS cutoff score of 7 created a 58% sensitivity rate, with less than 90% specificity in their study. In comparison, they achieved lower sensitivity (less than 30%) and more specificity (96%) when they used a cutoff score of 6. Zenisek et al. (2016) reported that the Digit Span is a well-validated test to check individual performances. However, they believed a lower

cutoff (≤6) could be more useful for measuring individual performance with memory issues. After conducting a study in an elementary school, Thursina et al. (2017) reported that the Backward Digit Span Test had good reliability with low validity to assess attention deficits of elementary school children.

Data Analysis Plan

The data analysis for this study was performed using the Statistical Package for the Social Sciences (SPSS) for Windows to provide a range of descriptive as well as inferential statistics, including statistical correlations. Researchers extensively use SPSS software in education as well as the social and behavioral sciences. The advantage of using SPSS is that it is user-friendly and enables a researcher to export data from Microsoft Excel easily. All required statistical tests for this study could be easily conducted in SPSS.

All data were preprocessed. Pre-processing aims to ensure a clean data set by excluding data outliers and missing data. Only those participants who had complete information on all variables were included in the data analysis. If a value was missing, the entire case was removed from the analysis (listwise deletion). In listwise deletion, a case is dropped from an analysis because it has a missing value in at least one of the specified variables. The complete, clean data set was utilized for the data analysis.

The following are the research questions and corresponding hypotheses guided and were addressed in this study:

RQ1: Do the SCAN-A test scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer’s disease?

$H1_0$: SCAN-A test scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H1_a$: SCAN-A scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

RQ2: Do the Speech-Sound Perception Test scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H2_0$: Speech-Sound Perception Test scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H2_a$: Speech-Sound Perception Test scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

RQ3: Do the Seashore Test scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H3_0$: Seashore Test scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H3_a$: Seashore Test scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

RQ4: Do the WMS-IV Logical Memory scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H4_0$: WMS-IV Logical Memory scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H4_a$: WMS-IV Logical Memory scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

RQ5: Do the WMS-IV Verbal Paired Associates scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H5_0$: WMS-IV Verbal Paired Associates scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H5_a$: WMS-IV Verbal Paired Associates scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

RQ6: Do the Digit Span (WAIS-IV) scores predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease?

$H6_0$: Digit Span (WAIS-IV) scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

$H6_a$: Digit Span (WAIS-IV) scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as Alzheimer's disease.

Descriptive analysis was conducted first to characterize the demographics of the participants as well as their responses to the survey. Descriptive statistics such as frequency, percentage, mean, and standard deviation were computed. Charts such as pie charts and histograms were generated to accompany the descriptive analysis.

The data plan included inferential statistical analyses, specifically logistic regression analysis, to examine the relationship between several neuropsychological evaluation test scores and diagnosis for Alzheimer's disease. Logistic regression was used to describe data and explain the relationship between one dependent binary variable and one or more nominal, ordinal, interval, or ratio-level independent variables (Nimon & Reio, 2011). For this study, the dependent variable, which is the diagnosis for AD, was

a binary variable (either yes or no), while the independent variables, which are the different neuropsychological evaluation test scores, were measured in interval/continuous form. Regression analysis serves three purposes: description, control, and prediction. Therefore, logistic regression analysis was appropriate for this study.

Since logistic regression analysis is considered a parametric test, certain assumptions must be met first before it can be used. There are five assumptions of logistic regression analysis, which include: (a) dependent variable must be binary, (b) independence of observations, (c) no multicollinearity among independent variables, (d) linearity of independent variables and log odds, and (e) large sample size required (Sedgwick, 2015). I tested all of these assumptions beforehand and ensured they were all met before I conducted any analysis. Hypothesis testing was done on all analyses with a 0.05 level of significance (Weakliem, 2016). This means that all p-value output of the hierarchical multiple regression was assessed using a 0.05 level of significance. A p-value of less than 0.05 dictates that there is a statistically significant relationship between the variables that the null hypothesis is rejected, whereas a value of greater than 0.05 dictates that a statistically significant relationship exists between the variables.

Threats to Validity

Researchers must recognize and mitigate threats to validity for their study. Three threats affecting this research study were construct, internal, and external validity. Addressing the threats strengthens the study, validates the research design method, and ensures the study is measuring what it claims to measure (Shadish et al., 2002).

Internal validity is the extent to which the researcher can conclude that the findings of the study are true (Leedy & Ormrod, 2012). As O'Dwyer and Bernauer

(2016) stated, internal validity is the approximate truth about inferences regarding cause-effect or causal relationships. O'Dwyer and Bernauer further explained that the key question in interval validity is whether observed changes can be attributed to an intervention, the cause or independent variable, and not to other possible causes or alternative explanations. If a study has a high degree of internal validity, then the researcher can conclude strong evidence of causality. Specific to this study, threats to internal validity in correlational research design included the issue of data normality and the existence of cofounding variables (Tharenou et al., 2007). To help mitigate the internal validity threat of instrumentation, this study only included valid and reliable instruments. Moreover, it ensured that the data gathered were accurate. The data came from a private consulting psychology practice located in Los Angeles County; therefore, the validity and reliability of the data should be acceptable.

External validity is related to generalization of results to a larger population (O'Dwyer & Bernauer, 2016). The design of this study did not allow me to generalize results beyond the study population. Moreover, the external validity threat in this study included the interaction of the relationship with settings and bounding by the age of the participants (Tharenou et al., 2007). Tharenou et al. (2007) stated that the interaction of relationship with settings poses the question of whether one kind of setting will hold if the interaction is done in a different setting. As this study's population was based on where adult individuals with memory problems reside or take medication, the interaction of relationship with setting could be a threat to generalizing to other populations based on location.

Ethical Procedures

This study began with IRB approval from the university to ensure ethical standards were met. The research was not expected to pose any harm to participants for several reasons. First, provided that the archival data had identifying information, I de-identified the participants to preserve confidentiality. Pseudo-codes were used to designate each case (i.e., C01) for case number one and so on. The data in this study were not in any way confidential, meaning that were anonymity to be somehow compromised, the risk of harm would remain minimal.

Hard copies of raw data and other documents pertinent to the study were securely kept in a locked filing cabinet inside my personal office. Soft copies of raw data and other documents were saved in a password-protected flash drive. All data and documents related to the study will be destroyed 7 years after completion of this dissertation. Hard copies will be shredded while soft copies will be deleted.

Summary

I used logistic regression to explain the relationship between the dependent variable (AD), a binary variable, and the independent variables (six different neuropsychological evaluation test scores) in interval/continuous forms. I used archival data, which I gathered from a database collected during the past 6 years (from 2015 to 2021) by a private consulting psychology practice after securing IRB approval. Utilizing G*Power while considering four factors in the power analysis (significance level, effect size, power of test, and statistical test) indicated that the minimum required sample size was 55.

This research proposed to study the predictability of SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), the Seashore Rhythm

(Seashore) Test (Seashore, 1915), Logical Memory (WMS-IV; Wechsler, 2009), Verbal Paired Associates (WMS-IV; Wechsler, 2009), and Digit Span (WAIS-IV; Wechsler, 2008) to diagnose neurodegenerative diseases (AD) at the early stage of the disease. I discuss the findings of this study in the next chapter.

Chapter 4: Results

Introduction

The purpose of this quantitative correlational study was to examine if tests of auditory working memory (WAIS-IV Digit Span; Wechsler, 2008), tests of sustained auditory attention (SCAN-A; Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), the Seashore Rhythm (Seashore) Test (Seashore, 1915), and tests of linguistic memory (Logical Memory, Verbal Paired Associates; Wechsler, 2009) significantly predicted whether an individual has been diagnosed with Alzheimer's disease (AD). The dependent variable was the presence of AD, and the independent variables were scores from the measures of digit span (forward, backward, and sequencing; Wechsler, 2008), SCAN-A (Keith, 1994), Seashore (Seashore, 1915), Speech-Sound Perception Test (Reitan & Wolfson, 1985), as well as Logical Memory and Verbal Paired Associates on the WMS-IV (Wechsler, 2009).

The first research question addressed if the SCAN-A test scores predicted the diagnosis for patients with a neurodegenerative disorder such as AD. The second question explored whether the Speech-Sound Perception Test scores predicted the diagnosis for patients with a neurodegenerative disorder such as AD. The third question examined if the Seashore Test scores predicted the diagnosis for patients with a neurodegenerative disorder such as AD. The fourth research question posed whether the WMS-IV Logical Memory scores predicted the diagnosis for patients with a neurodegenerative disorder such as AD. The fifth research question addressed if the WMS-IV Verbal Paired Associates scores predicted the diagnosis for patients with a neurodegenerative disorder such as AD. Finally, the sixth and last research question

examined if the WAIS-IV Digit Span scores predicted the diagnosis for patients with a neurodegenerative disorder such as AD. This chapter includes a description of the data collection process as well as a description of the sample that was recruited for the study. I also present the results of the statistical analyses that addressed the research questions. The chapter ends with a summary.

Data Collection

The final sample size for data analysis was 157, with 121 cases not having a dementia diagnosis and 36 having a dementia diagnosis. The data were collected from an archival convenience sample of individuals referred by their clinicians to a neuropsychological private practice located in Los Angeles County for neuropsychological evaluations. Initially, a total of 160 records of individuals were retrieved from the private practice located in Los Angeles County. The records were screened for missing data or inaccurate information. Although no inaccurate information was found, some test scores that were relevant to the study were missing. I decided not to exclude records or individuals with missing test scores because the sample size would have been greatly reduced by almost 50%. However, three participants were excluded from the final sample size because they were missing a dementia rating, which was the dependent variable for this study. As such, the final sample size for this study was 157. Table 1 presents how many of each independent variable were available for analysis.

Table 1

Sample Size for Each Independent Variable

Test Name	Dementia Group n	Non-Dementia Group n	Total N
SCAN-A Test	23	99	122
Speech-Sound Perception Test	17	67	84
Seashore Test	21	75	96
WMS-IV Logical Memory	36	121	157
WMS-IV Verbal Paired Associates	36	121	157
WMS-IV Digit Span	34	108	142

The majority of the sample was male (n = 87, 55.4%), and the average age was 58.3 years old (SD = 16.7). More than three-fourths of the cases included in the analysis had a diagnosis of dementia (n = 121, 77.1%). Table 2 presents the descriptive statistics of the demographic information of the participants.

Table 2

Description of Participants' Demographics (N = 157)

Gender	*N*	%
Male	87	55.4
Female	70	44.6
Dementia Rating	*N*	%
Yes	121	77.1
No	36	22.9

Table 3

Age and Gender Distribution

Diagnosis	Number of Cases	Mean Age (SD)	Gender Distribution	
Dementia	36	68.3 (16.68)	Male	15
			Female	21
No Dementia	121	48.3 (16.28)	Male	72
			Female	49

An independent t-test showed that there was a significant difference in the mean age of individuals with and without dementia, as those without the diagnosis were significantly younger ($t[155] = -5.531$, $p < .001$). Chi-square analysis showed that there was no significant association between dementia status and gender ($\chi^2[1] = 2.275$, $p = .131$). Given these findings, age was used as a covariate in the logistic regression analyses. The mean age calculated was 58.3 years and the SD was 16.70.

Results

I conducted binary logistic regression analyses to analyze if tests of auditory working memory (WAIS-IV Digit Span), tests of sustained auditory attention (SCAN-A), Speech-Sound Perception Test, the Seashore Rhythm Test, and tests of linguistic memory could significantly predict whether clients were diagnosed with dementia. Binary logistic regression is an appropriate statistical analysis when the purpose is to assess if a set of nominals, ordinal, or interval/ratio predictor variables predict a dichotomous dependent variable (Pituch & Stevens, 2015). This analysis permitted the evaluation of the odds of observing an outcome based on the combination of predictor variable values.

The use of binary logistic regression analysis requires data to meet four assumptions: (a) the dependent variable should be binary (dichotomous), (b) the independent variable should be either continuous or categorical, (c) observations should be independent, and (d) multicollinearity should be absent among the independent variables. Each of these assumptions was tested and all were met, indicating that binary logistic regression analyses could be conducted with the gathered data, as described below.

Assumption 1: Dependent Variable to Be Binary or Dichotomous

The dependent variable for this study was the dementia rating of the participants. Dementia rating can either be no dementia, very mild, mild, moderate, or severe. However, for this study, only two categories were used: cases with dementia or cases without dementia. Participants who were diagnosed with very mild, mild, moderate, or severe dementia were all categorized as cases with dementia. A score of "0" was assigned to cases where there was no diagnosis of dementia, while a score of "1" was assigned to cases with dementia regardless of severity rating. Therefore, the assumption that the dependent variable was binary or dichotomous was met.

Assumption 2: Independent Variable to Be Continuous or Categorical

This study's independent variables were the SCAN-A test scores, Speech-Sound Perception Test scores, Seashore Test scores, WMS-IV Logical Memory scores, WMS-IV Verbal Paired Associates, and WAIS-IV Digit Span scores. All these test scores were continuous variables. Therefore, the assumption that the independent variables should be continuous or categorical was met.

Assumption 3: Independence of Observations

The assumption of independence of observations suggests there is no relationship between the observations in each group or between the groups themselves (Hu & Plonsky, 2021; Kim, 2019). In other words, the measurements in each group are in no way influenced by or related to the measurements of the other group. In this study, the participants conducted the tests separately and were diagnosed based on their test scores. Thus, the assumption of independent observations was met.

Assumption 4: Absence of Multicollinearity Among Independent Variables

The final assumption of binary logistic regression was an absence of multicollinearity among the predictor variables. Multicollinearity refers to significant correlations among variables. This assumption was tested by calculating variance inflation factors (VIF). High VIFs indicate increased multicollinearity in the model. Specifically, VIF values over 10 suggested the presence of multicollinearity (Menard, 2002). Table 4 shows the VIF values of all the independent variables. All the VIF values of the predictor variables were below 10, which indicated that there were no significant correlations among the independent variables. Therefore, the assumption of the absence of multicollinearity among the independent variables was met.

Table 4

VIF for Independent Variables

Variable	VIF
SCAN-A Test Scores	1.483
Speech-Sound Perception Test Scores	1.197
Seashore Test Scores	1.328
WMS-IV Logical Memory Scores	2.659
WMS-IV Verbal Paired Associates	2.722
WAIS-IV Digit Span Scores	1.238

Research Question 1

The first research question asked whether the SCAN-A test scores could predict the diagnosis of neurodegenerative disorders such as AD in patients who were referred for memory impairment evaluation. For this research question, the independent variable was the SCAN-A test scores, and the dependent variable was the dementia rating (with or without dementia). The null and alternative hypotheses for this question were:

$H1_0$: SCAN-A test scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

$H1_a$: SCAN-A test scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

To test these hypotheses, I performed a binary logistic regression with SCAN-A test scores as the independent variable and dementia rating as the dependent variable. Age was included as a covariate. Table 5 presents the model summary. The Cox and Snell R Square and Nagelkerke R Square are two methods to calculate the explained

variation and can be used to determine the range of the explained variation. As shown in Table 5, the explained variation in the dependent variable (dementia rating) based on the binomial logistic model developed ranged from 21.8% to 35.1%. These values were low, indicating that the model did not adequately explain the variation in the dependent variable.

Table 5

Model Summary for Research Question 1

	-2 Log-Likelihood	Cox & Snell R Square	Nagelkerke R Square
Model	88.156	.218	.351

I conducted a logistic regression analysis to investigate Research Question 1. The predictor variable, SCAN-A test scores, was tested a priori to verify there was no violation of the assumption of the linearity of the logit. In addition, age was used as a covariate, as there was a significant group difference in age between cases with and without dementia. Both the SCAN-A test scores and age were found to contribute significantly to the model. The unstandardized Beta weight for the constant was significant ($\beta = -3.219$, SE = 1.600, Wald $\chi^2 = 4.049$, $p < .05$). The unstandardized Beta weight for SCAN-A test scores was significant ($\beta = -.037$, SE = .013, Wald $\chi^2 = 7.896$, $p < .05$). The unstandardized Beta weight for age was significant ($\beta = .058$, SE = .021, Wald $\chi^2 = 7.542$, $p < .05$). In other words, SCAN-A test scores and age both significantly predicted diagnosis for patients with a neurodegenerative disorder such as AD. Logistic regression analysis results for Research Question 1 are shown in Table 6.

Table 6

Variables in the Equation for Research Question 1

Variable	β	S.E.	Wald	df	Sig.	Exp(β)
SCAN-A Score	-.037	.013	7.896	1	.005	.964
Age	.058	.021	7.542	1	.006	1.060
Constant	-3.219	1.600	4.049	1	.044	.040

Overall, for individuals who were not diagnosed with dementia, there was an association between age and SCAN-A score. The older the individual was at the time of testing, the lower the SCAN-A score was. However, this association did not hold for individuals who were diagnosed with dementia; they tended to score low on the SCAN-A, regardless of age. Figure 1 shows this relation.

Research Question 2

The second research question explored whether the Speech-Sound Perception Test scores could predict the diagnosis of AD. For this research question, the independent variable was the Speech-Sound Perception Test scores, and the dependent variable was the dementia rating (with or without dementia). The null and alternative hypotheses for this question were:

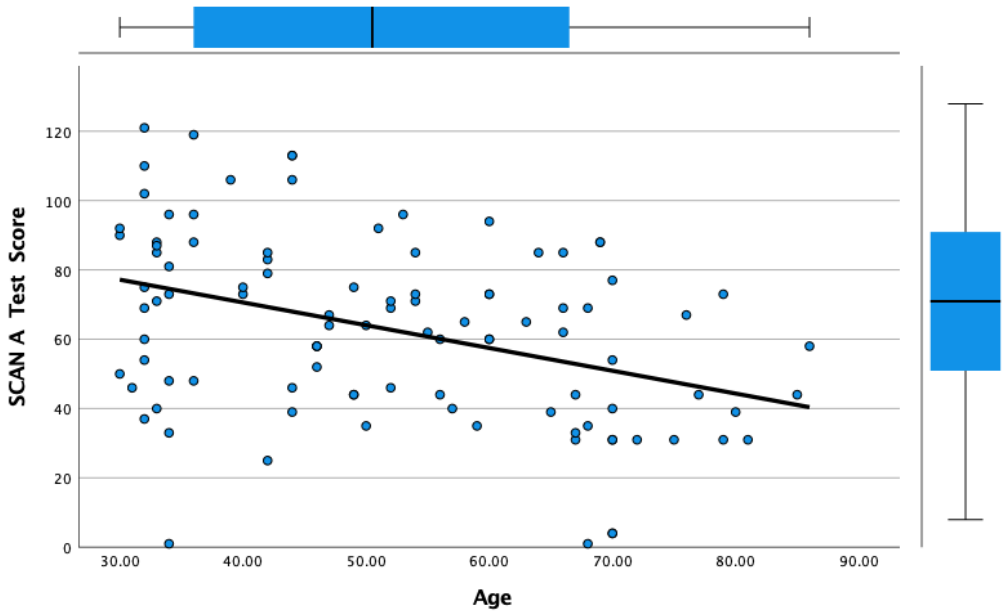
$H2_0$: Speech-Sound Perception Test scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

$H2_a$: Speech-Sound Perception Test scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

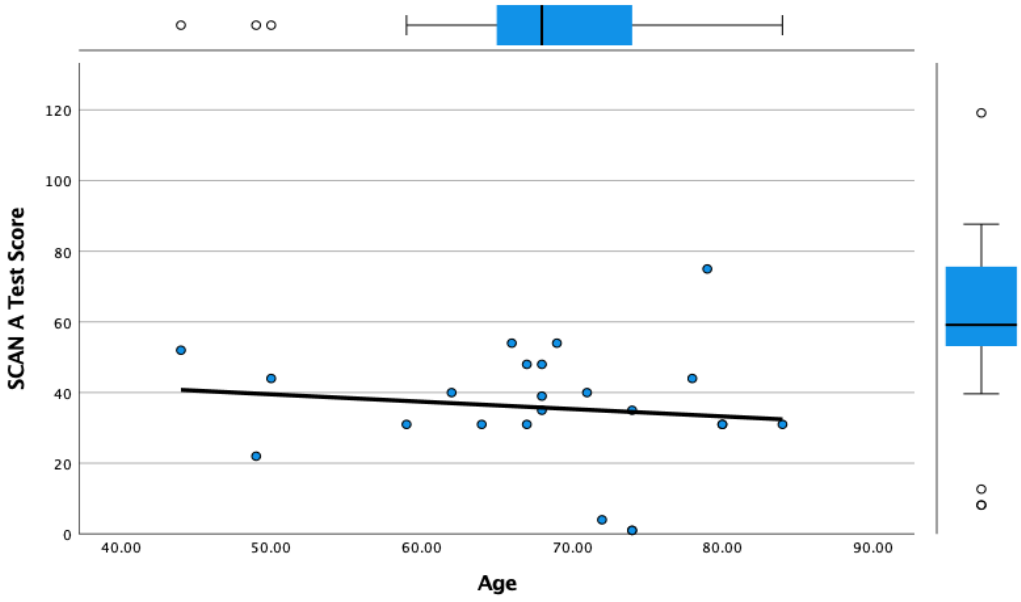
Figure 1

Association of Age and SCAN-A Score in Cases With and Without Dementia

Non-dementia cases, relation of age to SCAN A:



Dementia cases, relation of age to SCAN A:



To test these hypotheses, I performed binary logistic regression with Speech-Sound Perception Test scores as the independent variable and dementia rating as the dependent variable. Age was employed as a covariate. Table 7 presents the model summary, from which it can be inferred that the explained variation in the dependent variable (dementia rating) based on the binomial logistic model developed ranges from 24.9% to 39.2%. These values are low, indicating that the model does not adequately explain the variation in the dependent variable.

Table 7

Model Summary for Research Question 2

	-2 Log-Likelihood	Cox & Snell R Square	Nagelkerke R Square
Model	60.559	.249	.392

Speech-Sound Perception Test scores were found not to contribute to the model, but age did. The unstandardized Beta weight for the constant was significant ($\beta = -9.396$, SE = 2.539, Wald $\chi^2 = 13.700$, $p < .05$). The unstandardized Beta weight for Speech-Sound Perception Test scores was insignificant ($\beta = -.006$, SE = .027, Wald $\chi 2 = .049$, $p = .824$). The unstandardized Beta weight for age was significant ($\beta = .131$, SE = .040, Wald $\chi^2 = 10.780$, $p < .05$). Speech-Sound Perception Test scores did not significantly predict AD diagnosis. Logistic regression analysis results for Research Question 2 are shown in Table 8.

Table 8

Variables in the Equation for Research Question 2

Variable	B	S.E.	Wald	df	Sig.	Exp(β)
Speech-Sound Perception Score	-.006	.027	.049	1	.824	.994
Age	.131	.040	10.780	1	.001	1.140
Constant	-9.396	2.539	13.700	1	<.001	.000

Research Question 3

The third research question explored whether the Seashore Test scores could predict the diagnosis for patients with a neurodegenerative disorder such as AD. For this research question, the independent variable was the Seashore Test scores and the dependent variable was the dementia rating (with or without dementia). The null and alternative hypotheses for this question were:

$H3_0$: Seashore Test scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

$H3_a$: Seashore Test scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

To test these hypotheses, I performed a binary logistic regression with Seashore Test scores as the independent variable and dementia rating as the dependent variable. Age was used as a covariate. Table 9 presents the model summary, from which it can be inferred that the explained variation in the dependent variable (dementia rating) based on the binomial logistic model developed ranged from 27.8% to 42.7%. These values were

low, indicating that the model did not adequately explain the variation in the dependent variable.

Table 9

Model Summary for Research Question 3

	-2 Log-Likelihood	Cox & Snell R Square	Nagelkerke R Square
Model	69.611	.278	.427

Seashore Test scores were found not to contribute to the model, but age did. The unstandardized Beta weight for the constant was significant (β = -8.116, SE = 2.463, Wald χ^2 = 10.863, $p < .05$). The unstandardized Beta weight for Seashore Test scores was insignificant (β = -.042, SE = .042, Wald χ^2 = 1.001, $p = .317$). The unstandardized Beta weight for age was significant (β = .123, SE = .033, Wald χ^2 = 13.821, $p < .05$). In other words, Seashore Test scores did not significantly predict AD diagnosis. Logistic regression analysis results for Research Question 3 are shown in Table 10.

Table 10

Variables in the Equation for Research Question 3

Variable	β	S.E.	Wald	df	Sig.	Exp(β)
Seashore Score	-.042	.042	1.001	1	.317	.959
Age	.123	.033	13.821	1	<.001	1.131
Constant	-8.116	2.463	10.863	1	<.001	.000

Research Question 4

The fourth research question explored whether the WMS-IV Logical Memory scores could predict the diagnosis for patients with a neurodegenerative disorder such as AD. For this research question, the independent variable was the WMS-IV Logical Memory scores, and the dependent variable was the dementia rating (with or without dementia). The null and alternative hypotheses for this question were:

$H4_0$: WMS-IV Logical Memory scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

$H4_a$: WMS-IV Logical Memory scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

To test these hypotheses, I performed a binary logistic regression with WMS-IV Logical Memory scores as the independent variable and dementia rating as the dependent variable. Age was included in the equation as a covariate. Table 11 presents the model summary, from which it can be inferred that the explained variation in the dependent variable (dementia rating) based on the binomial logistic model developed ranged from 19.0% to 28.7%. These values were low, indicating that the model did not adequately explain the variation in the dependent variable.

Table 11

Model Summary for Research Question 4

	-2 Log Likelihood	Cox & Snell R Square	Nagelkerke R Square
Model	136.076	.190	.287

WMS-IV Logical Memory scores were found not to contribute to the model, but age did. The unstandardized Beta weight for the constant was significant (β = -5.839, SE = 1.203, Wald χ^2 = 23.564, $p < .05$). The unstandardized Beta weight for WMS-IV Logical Memory scores was insignificant (β = -.001, SE = .001, Wald χ^2 = 2.806, $p = .094$). The unstandardized Beta weight for age was significant (β = .076, SE = .017, Wald χ^2 = 18.945, $p < .05$). In other words, WMS-IV Logical Memory scores did not significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD. Logistic regression analysis results for Research Question 4 are shown in Table 12.

Table 12

Variables in the Equation for Research Question 4

Variable	B	S.E.	Wald	df	Sig.	Exp(β)
WMS-IV Logical Memory Score	-.001	.001	2.806	1	.094	.999
Age	.076	.017	18.945	1	<.001	1.079
Constant	-5.839	1.203	23.564	1	<.001	.003

Research Question 5

The fifth research question explored if the WMS-IV Verbal Paired Associates scores could predict the diagnosis for patients with a neurodegenerative disorder such as AD. For this research question, the independent variable was the WMS-IV Verbal Paired Associates scores, and the dependent variable was the dementia rating (with or without dementia). The null and alternative hypotheses for this question were:

$H5_0$: WMS-IV Verbal Paired Associates scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

$H5_a$: WMS-IV Verbal Paired Associates scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

To test these hypotheses, I performed a binary logistic regression with WMS-IV Verbal Paired Associates scores as the independent variable and dementia rating as the dependent variable. Age was included in the equation as a covariate. Table 13 presents the model summary, from which it can be inferred that the explained variation in the dependent variable (dementia rating) based on the binomial logistic model developed ranged from 17.4% to 26.3%. These values were low, indicating that the model did not adequately explain the variation in the dependent variable.

Table 13

Model Summary for Research Question 5

	-2 Log Likelihood	Cox & Snell R Square	Nagelkerke R Square
Model	139.147	.174	.263

WMS-IV Verbal Paired Associates in the logistic regression analysis was found not to contribute to the model, but age did. The unstandardized Beta weight for the constant was significant ($\beta = -6.107$, $SE = 1.184$, Wald $\chi^2 = 26.610$, $p < .05$). The unstandardized Beta weight for WMS-IV Verbal Paired Associates was insignificant ($\beta = .000$, $SE = .000$, Wald $\chi^2 = .142$, $p = .707$). The unstandardized Beta weight for age was significant ($\beta = .078$, $SE = .017$, Wald $\chi^2 = 20.066$, $p < .05$). In other words, WMS-IV Verbal Paired Associates did not significantly predict AD diagnosis. Logistic regression analysis results for Research Question 5 are shown in Table 14.

Table 14

Variables in the Equation for Research Question 5

Variable	β	S.E.	Wald	df	Sig.	Exp(β)
WMS-IV Verbal Paired Associates Score	.000	.000	.142	1	.707	1.000
Age	.078	.017	20.066	1	<.001	1.081
Constant	-6.107	1.184	26.610	1	<.001	.002

Research Question 6

The sixth research question explored whether the WMS-IV Digit Span scores could predict the diagnosis for patients with a neurodegenerative disorder such as AD. For this research question, the independent variable was the WMS-IV Digit Span scores, and the dependent variable was the dementia rating (with or without dementia). The null and alternative hypotheses for this question were:

$H6_0$: WAIS-IV Digit Span scores do not significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

$H6_a$: WAIS-IV Digit Span scores significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD.

To test these hypotheses, I performed a binary logistic regression with WAIS-IV Digit Span scores as the independent variable and dementia rating as the dependent variable. Age was included as a covariate. Table 15 presents the model summary, from which it can be inferred that the explained variation in the dependent variable (dementia rating) based on the binomial logistic model developed ranged from 20.2% to 30.3%.

These values were low, indicating that the model did not adequately explain the variation in the dependent variable.

Table 15

Model Summary for Research Question 6

	-2 Log Likelihood	Cox & Snell R Square	Nagelkerke R Square
Model	124.274	.202	.303

WAIS-IV Digit Span scores did not significantly contribute to the model, but age did. The unstandardized Beta weight for the constant was significant (β = -5.368, *SE* = 1.397, Wald χ^2 = 14.756, $p < .05$). The unstandardized Beta weight for WMS-IV Digit Span scores was insignificant (β = -.112, *SE* = .066, Wald χ^2 = 2.854, p = .091). The unstandardized Beta weight for age was significant (β = .081, *SE* = .019, Wald χ^2 = 18.746, $p < .05$). In other words, WAIS-IV Digit Span scores did not significantly predict the diagnosis for patients with a neurodegenerative disorder such as AD. Logistic regression analysis results for Research Question 6 are shown in Table 16.

Table 16

Variables in the Equation for Research Question 6

Variable	β	S.E.	Wald	df	Sig.	Exp(β)
WAIS-IV Digit Span Score	-.112	.066	2.854	1	.091	.894
Age	.081	.019	18.746	1	<.001	1.085
Constant	-5.368	1.397	14.756	1	<.001	.005

Summary

This study examined whether the dependent variable AD (dementia rating) could be significantly predicted by the values of the independent variables, including the SCAN-A (Keith, 1994), the Speech-Sound Perception Test (Reitan & Wolfson, 1985), the Seashore Rhythm (Seashore) Test (Seashore, 1915), the Logical Memory (WMS-IV; Wechsler, 2009), Verbal Paired Associates (WMS-IV; Wechsler, 2009), and the Digit Span (WAIS-IV; Wechsler, 2008) test scores. I used archival data from private neuropsychological practice in Los Angeles County for this study. Study participants were individuals referred by their clinicians to this office for neuropsychological evaluation. The final sample size was 157 cases.

After testing and meeting the assumptions of the analysis, I conducted a binary logistic regression analysis. Binary logistic regression analyses were used to analyze if tests of WAIS-IV Digit Span, the SCAN-A, the Speech-Sound Perception Test, the Seashore Rhythm Test, and tests of Logical Memory and Verbal Paired Associates could significantly predict whether clients were diagnosed with dementia. There was a significant difference in the mean age of individuals with and without dementia; therefore, age was used as a covariate in the logistic regression analyses.

The binary logistic regression analysis results indicated that the null hypothesis for Research Question 1 could be rejected, whereas the null hypotheses for Research Questions 2 through 6 were retained. Specifically, SCAN-A test scores were a significant predictor of dementia rating, taking age into account. In contrast, the Speech-Sound Perception Test, the Seashore Test, the WMS-IV Logical Memory, the WMS-IV Verbal Paired Associates, and the WAIS-IV Digit Span Test scores were not significant

predictors of dementia rating, using age as a covariate. Chapter 5 provides a discussion and conclusions about the results and presents recommendations for future research.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this quantitative nonexperimental study was to determine whether tests of auditory working memory (WAIS-IV Digit Span [Wechsler, 2008]); tests of sustained auditory attention (SCAN-A [Keith, 1994]; Speech-Sound Perception Test [Reitan & Wolfson, 1985]; Seashore Rhythm Test [Seashore, 1915]); and tests of linguistic memory (Logical Memory, Verbal Paired Associates [Wechsler, 2009]) predicted Alzheimer's disease (AD) diagnosis in patients with this disease. This chapter begins by interpreting the findings of this study. Limitations of the study and recommendations for future research are addressed, followed by implications for positive social change.

Nature of the Study

I developed a quantitative nonexperimental design for this study to examine my research questions. I used the following validated and reliable assessment tools: SCAN-A (Keith, 1994), Speech-Sound Perception Test (Reitan & Wolfson, 1985), Seashore Rhythm Test (Seashore, 1915), Logical Memory Test, Verbal Paired Associates Test (Wechsler, 2009), and Digit Span (WAIS-IV; Wechsler, 2008) to find out if they had some correlation with the age and probability of occurrence of AD in patients with this disease. Studies by Pituch and Stevens (2015), for example, revealed that these six diagnostic tools are the most applied in AD diagnosis. I used logistic regression analysis to address the research questions and test the hypotheses. Pituch and Stevens agreed that binary logistic regression is an appropriate statistical analysis to study if a set of nominals, ordinals, or interval/ratio predictor variables predicts a dichotomous dependent

variable. This quantitative non-experimental quantitative design was useful for determining if the independent variables, such as scores from the measures of digit span (forward, backward, and sequencing; Wechsler, 2008), SCAN-A (Keith, 1994), Seashore (Seashore, 1915), Speech-Sound Perception Test (Reitan & Wolfson, 1985), and Logical Memory and Verbal Paired Associates on the WMS-IV (Wechsler, 2009) predicted a diagnosis of AD in patients with this disease. The primary source for data collection was archival data from a database collected during the past 6 years (from 2015 to 2021) by a private consulting psychology practice to conduct this present research.

The target population in this research was individuals 30 years old or older who were referred by their clinicians to the neuropsychological private practice for neuropsychological evaluation. Initially, I retrieved the data of 160 participants for this study, as these individuals did not have dementia ratings—the dependent variable for this study. Therefore, the final sample size for this study was 157.

Summary of the Findings

An examination of the sample demographics showed a significant difference in the mean age of study participants with and without dementia. Individuals without the diagnosis of dementia were significantly younger ($t[155] = -5.531$, $p < .001$), compared to those with the diagnosis of dementia. Therefore, age was used as a covariate in the logistic regression analysis. Six main analyses were conducted to investigate if there was any meaningful relationship between the scores of these cognitive tests and AD. The data showed that SCAN-A test scores and age both significantly predicted AD diagnosis in the sample. Being older and having a SCAN-A standard score below the normal range significantly predicted a neurodegenerative disease diagnosis. However, WMS-IV

Logical Memory, Speech-Sound Perception Test, Seashore Rhythm Test, Verbal Paired Associates Test, and Digit Span did not predict a dementia diagnosis.

Interpretation of the Findings

This study showed that only one independent variable, the SCAN-A test score, significantly predicted the dependent variable. None of the other five independent variables significantly predicted the dependent variable, although Logical Memory and Digit Span both demonstrated trends (p = .094 and .091, respectively) along with significant values for the covariate of age. This contradicted other prior studies reviewed in the literature review section. Regarding Logical Memory (LM) as one of the WMS-IV subtests, Soble et al. (2019) described LM measures auditory-verbal contextual learning and memory with superb reliability and validity. Morey and Cowan (2005) reported that verbal or linguistic memory could be detected by LM and Verbal Paired Associate tests. According to Indrani et al. (2015), the Verbal Paired Associates is an excellent test for assessing memory and detecting verbal or linguistic memory issues. Cleary et al. (2018) agreed that the Digit Span test could measure short-term memory, immediate recall, and working memory. Richardson (2007) reported that the Digit Span is a valuable test for measuring individual performance with memory issues. The Digit Span (forward and backward) test is one of the oldest and most widely used neuropsychological tests for studying short-term verbal memory (Richardson, 2007). Some of the inconsistencies noted between this study's findings and past studies for example, with regard to the verbal paired-associate tests may have resulted from varying factors between studies such as the time of data collection, the validity and reliability of research instruments, and the context of the study. Indrani et al. (2015), for instance, conducted the Verbal Paired

Associates study close to 7 years ago at a time when the relationship between age and healthcare was slightly different from the current relationship between these two variables. In Indrani et al.'s study, participants were younger individuals with a mean age of 19.6. These individuals did not report any signs and symptoms of AD. In 2018, only 3 years after this study, the population aged 65 and older numbered 52.4 million, and this number is even much higher currently. Twenty percent of Americans will be 65 or older by 2030. It underscores the importance of considering the capacity to improve the health and well-being of older adults. The number of cases with dementia diagnoses was also relatively low in the present study, which may have resulted in lower power to detect predictive relations among variables. The age of the individuals without dementia was significantly lower than those with dementia; although the analyses took this into account, this reality may have impacted the findings.

One of the six independent variables analyzed for this study, the SCAN-A test scores, was the only variable that significantly predicted the dependent variable. SCAN-A test scores significantly predicted the diagnosis of a neurodegenerative disorder such as AD. The results of the logistic regression equation showed that both the SCAN-A test scores and age predicted diagnosis for patients with a neurodegenerative disorder such as AD. However, when the groups were examined independently in scatterplots, it did appear that while age was related to the SCAN-A score for cases without AD, cases with AD had low SCAN-A scores regardless of age. This indicates a need for continued research, with a focus on this particular scale, especially when the individuals being tested are in their 50s or 60s. The younger AD cases in the sample used in this study was

too insufficient to make clear conclusions; however, future research is warranted to identify the utility of the SCAN-A in the diagnostic process.

Logical Memory and Digit Span also demonstrated trends along with significant values for the covariate of age. I did not find any statistically significant relationship between Verbal Paired Associates scores, the Seashore and Speech-Sound Perception scores, and diagnosis of a neurodegenerative disorder such as AD. However, a consistency was noted between the findings of this study and previous studies discussed in the literature review section. For example, Soble et al. (2019) emphasized the role of Logical Memory to diagnose memory impairment. Also, Cleary et al. (2018) and Richardson (2007) agreed that the Digit Span Test could assess memory to some degree. It is possible that a small sample size limited my ability to detect a significant predictive relation between these tests and an AD diagnosis, but the findings of trends for those variables partially supported the findings in the studies of Soble et al. and Cleary.

There was also some inconsistency between my findings and the literature, given that Morey and Cowan (2005) and Indrani et al. (2015) asserted that Verbal Paired Associate tests could detect memory issues. I did not identify an association between Verbal Paired Associate scores and AD in the logistical regression analyses, as the results supported the null hypotheses for Research Questions 4 and 6. Given this disparity, further research is still warranted as participants in both the Morey and Cowan and Indrani et al. studies were students with no AD history. Morey and Cowan (2005) selected 26 students between the ages of 18 and 24 without a history of AD, whereas Indrani et al. (2015) used 103 students with a mean age of 19.6 and no AD diagnosis.

According to the findings of the present study, the SCAN-A might be a promising

test for clinicians to better identify patients with AD, particularly at younger ages. This test is dependable, measurable, noninvasive, reproducible, and affordable. Licensed health psychologists or doctoral-level clinical psychology students who have been trained to administer, score, and interpret this test can do so relatively quickly and easily. Future research using this tool is highly recommended, both as a diagnostic tool and a potential tool to identify early onset AD, given that these uses of the SCAN-A were beyond the scope of the study.

Limitations

This study has several limitations. One limitation is that I expanded the age range to include individuals aged 30 or older to achieve the needed sample size. After reviewing 95 different studies and three million patients, Hendriks et al. (2021) reported that young-onset dementia in individuals aged 30 to 64 years had a low prevalence (119.0 per 100,000 population). Kvello-Alme et al. (2019) stated that neurodegenerative diseases are rare before the age of 45. Only 4% of AD cases appeared in younger individuals who were 65 years old or younger (Baillon et al., 2019). The study sample should represent the target population (Martínez-Mesa et al., 2016). Because AD prevalence is rare in individuals younger than 65 (Hendriks et al., 2021), this study sample might not represent the population. Therefore, sample size was a limitation for this study since only 36 individuals out of 157 participants were diagnosed with dementia. The ages of the individuals with AD were older than those without AD, which limits the interpretation of the findings. Other AD factors that were not taken into account

include time since diagnosis and severity of the disease, which may also impact the findings.

The geographical location of the cases was another significant limitation, as well as the fact that the sample was taken from a group of individuals who had sought out testing at a private clinic. The sample was a select group of individuals who likely differed from the general population in terms of social class, education, income, cultural, and racial factors. Lang et al. (2017) reported a relationship between socioeconomic level and undetected dementia, with those in low-SES groups experiencing a high rate of undiagnosed demential symptoms. Low SES is also a factor in not accessing medical health care (Becker & Newsom, 2003). Individuals with lower SES are more likely uninsured or have health insurance with high deductibles or copays. People in low-SES groups tend to not seek medical help except for emergencies (Becker & Newsom, 2003). With the current growth in levels of awareness of disparity in healthcare access in research, Lang et al. (2017) indicated that the lack of consideration of racial equality during sampling can also result in study bias. This was one of the limitations that faced this study as I did not collect demographic variables such as race, education, and SES in the sample. There were also limitations in consideration of AD severity or length of diagnosis.

Another limitation of this study is the lack of knowledge about individuals' hearing status. The data were collected from an archived sample, so prospective assessment of hearing was not possible, nor did I have control of the testing process. If participants suffer from a hearing impairment, the test results might be inaccurate based on the level of their auditory impairment, despite adjusting the volume, talking more

loudly to the examinee, and using the headset. When examiners conducted some of the cognitive tests (e.g., tests of sustained auditory attention [SCAN-A; Keith, 1994], Speech-Sound Perception Test [Reitan & Wolfson, 1985], Seashore Rhythm Test [Seashore, 1915]), they needed to speak to examinees, and examinees needed to use a headset to hear the test instructions. The researcher was, however, working under the assumption that all examinees had healthy auditory skills, and so they were able to hear all instructions. There was, however, a probability that some of the examinees could have had undetected or undiagnosed hearing challenges that might have affected the clarity with which they heard and, therefore, understood the test instructions, especially given that the majority of the cases included in the sample were older.

Recommendations

Future research with a larger sample size is needed since this study only focused on cases of individuals who were referred to a neuropsychological private practice, and the number of cases with dementia was limited. Regarding this, Faber and Fonseca (2014) explained that the drawback of having a small sample size first is that this heightens the chance of presuming false premises as factual. In addition, to ensure that the size of a sample is adequately representative, researchers must take into account different factors such as age, gender, ethnicity, education, marital status, economic status, and diagnoses such as depression, anxiety, or other medical issues and study how these specific cognitive tests can facilitate the diagnosis of AD in this group of patients.

Future research should focus on examining the accuracy of other tests in identifying memory issues in addition to the six that were examined in this study: SCAN-A, Speech-Sound Perception Test, Seashore Rhythm Test, Logical Memory Test, Verbal

Paired Associates Test, and Digit Span Test. Other potential screening tests that were not assessed in this study include immittance audiometry, auditory brainstem response (ABR), otoacoustic emissions, and auditory middle latency response (AMLR). Results from such studies would possibly detect tests that may be added to a testing battery to increase the accuracy of diagnosis. According to Harris (2010), an integrative approach to diagnosis including psychological and physiological testing would ensure patient satisfaction. Healthcare providers can work more closely together to give better outcomes for patients with illness management, mental health difficulties, and physical therapy, among other important concerns. This would improve their entire quality of life and their overall happiness with their healthcare provider as a result.

Integrated healthcare, according to Harris (2010), improves overall quality of care. Healthcare professionals can work together more closely to understand the unique needs of each patient, create a customized treatment plan, and ensure that patients are receiving appropriate treatment to improve their overall well-being. The integrated approach to healthcare, according to Harris, also helps keep expenses down. Adding the SCAN-A to a clinical testing battery takes little time and effort, yet the findings of this research indicated that it may be a useful component of a full testing battery. Precise diagnosis requires multiple healthcare professionals working together so that patients can receive the care they need with fewer visits. As part of an integrated healthcare approach, patients and healthcare providers alike can benefit from faster diagnosis and the elimination of unnecessary medical tests and exams (Harris, 2010).

My findings also suggested that the SCAN-A can be used to note potential AD diagnosis, especially in younger individuals with AD; however, this does not mean that

the SCAN-A is an early detection tool. Further research is necessary to determine the full utility of the SCAN-A in a testing battery before any conclusions can be drawn about its specific purpose in that battery. The results from this study may be used as a basis to strengthen AD treatment centers to offer more help to individuals with an AD diagnosis. An increased ability to identify AD may be used to improve treatment, given the alarming prevalence of AD. According to Giau et al. (2019), AD is the most common form of neurodegenerative disease (50% to 75% of all forms of dementia are diagnosed as AD). Almost 4.6 million individuals are diagnosed with AD annually (Giau et al., 2019). Even though some familial and early-onset AD appears before the age of 65 and is related to genetic variants linked to amyloid-β, the number of cases is much less than the late-onset AD.

The other recommendation concerns the study of AD testing and treatment in line with racial implications. Research that is focused on AD needs to be expanded to include individuals from multiple racial and ethnic groups, as well as individuals from a variety of educational backgrounds and SES level. Canevelli et al. (2019) opined that the relation between AD and race had not been studied and documented sufficiently. Studies that focus on the level of access to AD care services based on race would help interested organizations to come up with strategies to ensure disparity along racial lines when it comes to increasing access and reducing the affordability of AD services. Canevelli et al. particularly underscored the importance of this recommendation with the fact that access to medical care is currently influenced significantly by the racial identities of those seeking medical care.

This study focused only on a set of six tests that were included in a standard

testing battery, and the SCAN-A, which was found to have a significant predictive relation to AD diagnosis, is composed of four subtests (Filtered Words, Auditory Figure-Ground, Competing Words, and Competing Sentences). I did not examine if any of those subtests were responsible for the relationship with AD, and future research may investigate these relationships. Also, the Digit Span Test has separate forward, backward, and sequencing scores, but only the total Digit Span scores were included in the analysis. Researchers may study the relationship between each of these subtests and AD.

Implications and Positive Social Change

Potential Impact at the Individual, Family, and Healthcare Level

According to Merz and Spitzer (1998), SCAN-A is a screening test for Auditory Processing Disorders. This test can screen speech perception problems and central auditory processing disorders. The administration of the SCAN-A test is very straightforward. Examiners only need to have simple equipment such as a regular cassette player with headphones, the test manual, and record forms to administer this test (Merz & Spitzer, 1998). Lower scores on the SCAN-A in younger individuals could serve as a red flag and should be considered for a more comprehensive testing battery; clinicians should look at their other tests and scores. Early diagnosis can provide better medical intervention (Jayakody et al., 2020) and give patients and their families a chance to plan for their future and take care of financial and legal matters. Future research should investigate whether the SCAN-A can be used as an early detection tool.

Taking care of AD patients can be very expensive: Institutionalization for AD patients costs more than 100 billion dollars annually (Leifer, 2003). After cardiovascular disease and cancer, AD is the third most costly disease in the United States (Leifer,

2003). The cost of treatment for AD patients depends on their disease severity, varying between 50 to 100 billion dollars in a year (Leifer, 2003). Testing and early detection can result in early treatment, which benefits the individual with the diagnosis as well as their families, treating professionals, and society in general. Any research that helps the scientific community advance toward easier and more cost-efficient diagnosis of AD provides an opportunity to create positive social change.

Sometimes AD mimics depression and delirium signs and symptoms. The findings of this study may lead to improved testing that increases the chance of identifying the neurocognitive disorders in a neuropsychological screening, leading to accurate diagnosis and proper treatment. As Jayakody et al. (2020) emphasized, early AD diagnosis can provide quality medical intervention. Early AD diagnosis allows patients access to available treatments and interventions. Patients will have the chance to arrange their care team, attend a support group, or enroll in clinical trials. At the earlier stage of their disease, while they are still functional, patients and their caregivers could arrange a system to manage their medications and finances and address any other potential challenges. Rasmussen and Langerman (2019) believed that early AD diagnosis would allow patients to access different treatments to manage AD symptoms. Early diagnosis could also delay dementia's onset, which benefits patients and their families and significantly reduces the cost of taking care of these patients. Therefore, early diagnosis could save a considerable amount of money for the healthcare system.

This study's findings and recommendations may also result in more research regarding developing a holistic testing protocol for AD to come up with an integrated approach to diagnosis. Accurate diagnosis of AD implies that effective treatments may be

delivered quickly. Early and proper diagnosis and treatment help the AD patients and their families plan for the future and may help patients function for a more extended time. Healthcare providers will have more tools to select for diagnosing their patients, and their diagnosis could be more accurate. Dementia care is costly, and any intervention that helps with early diagnosis and treatment could benefit society in terms of financial and emotional costs.

Conclusion

In this study, I investigated if selected tests (SCAN-A, Speech-Sound Perception Test, Seashore Rhythm Test, Logical Memory Test, Verbal Paired Associates Test, and Digit Span Test) could significantly predict the diagnosis of AD in individuals. A significant predictive relationship was found between the SCAN-A scores and age in the prediction of AD and also trends in Logical Memory and Digit Span in predicting AD diagnosis. The Speech-Sound Perception Test, the Seashore Test, the WMS-IV Logical Memory, the WMS-IV Verbal Paired Associates, and the WAIS-IV Digit Span Test scores did not predict AD diagnosis. Age was significantly predictive of diagnosis in all regression equations, as expected. Only SCAN-A test scores could significantly predict patients with a neurodegenerative disorder such as AD, with cases of patients with AD scoring poorly regardless of age, while cases without AD demonstrated a strong association between score and age.

Clinicians use the SCAN-A (Keith, 1994) for adolescents and adults as a component of neuropsychological testing. This test is valuable for identifying auditory processing issues in adolescents and adults (Keith, 1994). The SCAN-A test is an excellent tool to describe auditory processing abilities, central auditory abilities, and

functional impairment in individuals with chronic central nervous system disease (Keith, 1994). It is easy to perform and requires approximately 20 minutes to administer. Sometimes clinicians use the SCAN-A as an additional test to diagnose learning disabilities in adults.

This study showed that the SCAN-A test might be helpful as an addition to test batteries in identifying possible AD. This test is reliable, assessable, noninvasive, repeatable, and inexpensive. It can be administered by licensed clinical psychologists or doctoral-level clinical psychology students trained to administer, score, and interpret this test. Based on the findings of this study, the SCAN-A test would make a valuable addition as a screening tool in the assessment of possible neurodegenerative diseases such as AD.

References

Agrawal, M., & Biswas, B. (2015). Molecular diagnostics of neurodegenerative disorders. *Frontiers in Molecular Biosciences, 2*. https://doi.org/10.3389/fmolb.2015.00054

Alexander, M., Blackburn, D., & Reuber, M. (2019). Patients' accounts of memory lapses in interactions between neurologists and patients with functional memory disorders. *Sociology of Health and Illness, 41*(2), 249–265. https://doi.org/10.1111/1467-9566.12819

Al-Hameed, S., Benaissa, M., Christensen, H., Mirheidari, B., Blackburn, D., & Reuber, M. (2019). A new diagnostic approach for the identification of patients with neurodegenerative cognitive complaints. *PLoS ONE, 14*(5), e0217388. https://doi.org/10.1371/journal.pone.0217388

American Psychological Association. (2020). Glossary of psychological terms. Retrieved from. http://www.apa.org/research/action/glossary.aspx#

Arroyo-Anllo, E. M., Dauphin, S., Fargeau, M. N., Ingrand, P., & Gil, R. (2019). Music and emotion in Alzheimer's disease. *Alzheimer's Research and Therapy, 1*. https://doi.org/10.1186/s13195-019-0523-y

Babbie, E. R. (2013). *The practice of social research*. Wadsworth.

Baddeley, A. D. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology, 63*, 1–29.

Baillon, S., Gasper, A., Wilson-Morkeh, F., Pritchard, M., Jesu, A., & Velayudhan, L. (2019). Prevalence and severity of neuropsychiatric symptoms in early- versus

late-onset Alzheimer's disease. *American Journal of Alzheimer's disease and Other Dementias, 34*(7–8), 433–438. https://doi.org/10.1177/1533317519841191

Baron-Cohen, S., Jolliffe, T., Mortimore, C., & Robertson, M. (1997). Another advanced test of theory of mind: Evidence from very high-functioning adults with autism or Asperger syndrome. *Journal of Child Psychology and Psychiatry, 38,* 813–822.

Becker, G., & Newsom, E. (2003). Socioeconomic status and dissatisfaction with health care among chronically ill African Americans. *American Journal of Public Health, 93*(5), 742–748. https://doi.org/10.2105/ajph.93.5.742

Bejanin, A., Chetelat, G., Laisney, M., Pelerin, A., Landeau, B., Merck, C., Belliard, S., de La Sayette, V., Eustache, F., & Desgranges, B. (2017). Distinct neural substrates of affective and cognitive theory of mind impairment in semantic dementia. *Social Neuroscience, 12*(3), 287–302. https://doi.org/10.1080/17470919.2016.1168314

Berger, J., & Bayarri, M. J., & Pericchi, L. R. (2013). The effective sample size. *Econometric Reviews*, *33*(1-4), 197–217. http://doi.org/10.1080/07474938.2013.807157

Bujang, M. A., Ghani, P. A., Zolkepali, N. A., Selvarajah, S., & Haniff, J. (2012). A comparison between convenience sampling versus systematic sampling in getting the true parameter in a population: Explore from a clinical database: The Audit Diabetes Control Management (ADCM) registry in 2009. *2012 International Conference on Statistics in Science, Business and Engineering (ICSSBE),* 1–5. https://doi.org/10.1109/ICSSBE.2012.6396615

Camm, J. D. (2012). *Quantitative methods for business* (12th, International ed.). South-Western.

Canevelli, M., Bruno, G., Grande, G., Quarata, F., Raganato, R., Remiddi, F., Valletta, M., Zaccaria, V., Vanacore, N., & Cesari, M. (2019). Race reporting and disparities in clinical trials on Alzheimer's disease: A systematic review. *Neuroscience and Biobehavioral Reviews*, *101*, 122–128. https://doi.org/10.1016/j.neubiorev.2019.03.020

Carl, B. D., & Sureyya, S. D. (1978). The Seashore Tonal Memory Test as a neuropsychological measure. *Journal of Consulting and Clinical Psychology*, *46*(1), 192–193.

Ciaramelli, E., Bernardi, F., & Moscovitch, M. (2013). Individualized theory of mind (ITOM): When memory modulates empathy. *Frontiers in Psychology*, *4*, 4. doi:10.3389/fpsyg. 2013.00004

Cleary, M., Wilkinson, T., Wilson, L., & Goupell, M. J. (2018). Memory Span for Spoken Digits in adults with cochlear implants or typical hearing: Effects of age and identification ability. *Journal of Speech, Language, and Hearing Research*, *61*(8), 2099–2114. https://doi.org/10.1044/2018_JSLHR-H-17-0245

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Academic Press. Retrieved from http://www.utstat.toronto.edu/~brunner/oldclass/378f16/readings/CohenPower.pdf

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed). Pearson.

Curtis, K. L., Greve, K. W., Brasseux, R., & Bianchini, K. J. (2010). Criterion groups validation of the Seashore Rhythm Test and Speech Sounds Perception Test for the detection of malingering in traumatic brain injury. *Clinical Neuropsychologist, 24*(5), 882–897.

De Lucena, A. T., Bhalla, R. K., Dos Santos, T. T. B. A., & Dourado, M. C. N. (2020). The relationship between theory of mind and cognition in Alzheimer's disease: A systematic review. *Journal of Clinical and Experimental Neuropsychology, 42*(3), 223–239. https://doi.org/10.1080/13803395.2019.1710112

Diekfuss, J. A., De Larwelle, J., & McFadden, S. H. (2018). Diagnosis makes a difference: Perceptions of older persons with dementia symptoms. *Experimental Aging Research, 44*(2), 148–161. https://doi.org/10.1080/0361073X.2017.1422475

Dodrill, C. B., & Dikmen, S. S. (1978). The Seashore Tonal Memory Test as a neuropsychological measure. *Journal of Consulting and Clinical Psychology, 46*(1), 192–193. https://doi.org/10.1037/0022-006X.46.1.192

Elfil, M., & Negida, A. (2016). Sampling methods in clinical research; an educational review. *Emergency, 1,* e52. https://doi.org/10.22037/ emergency.v5i1. 15215

Faber, J., & Fonseca, L. M. (2014). How sample size influences research outcomes. *Dental Press Journal of Orthodontics, 19*(4), 27–29. https://doi.org/10.1590/2176-9451.19.4.027-029.ebo

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2013). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*(4), 1149–1160.

Fiorini, L., Maselli, M., Castro, E., Tocchini, S., Sportiello, M. T., Laschi, C., Cecchi, F., & Cavallo, F. (2017). Feasibility study on the assessment of auditory sustained attention through walking motor parameters in mild cognitive impairments and healthy subjects. *2017 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC),* 897–900. https://doi.org/10.1109/ EMBC.2017.8036969

Ford, A. H., Hankey, G. J., Yeap, B. B., Golledge, J., Flicker, L., & Almeida, O. P. (2018). Hearing loss and the risk of dementia in later life. *Maturitas, 112,* 1–11. https://doi.org/10.1016/j.maturitas.2018.03.004

Fritsch, J., Wankerl, S., & Nöth, E. (2019). Automatic diagnosis of Alzheimer's disease using neural network language models. ICASSP 2019–2019 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). http://dx.doi.org/10.1109/ICASSP.2019.8682690

Fuente, A., & McPherson, B. (2006). Auditory processing tests for Spanish-speaking adults: An initial study. *International Journal of Audiology, 45*(11), 645–659. https://doi.org/10.1080/14992020600937238

Gates, G. A., Anderson, M. L., Feeney, M. P., McCurry, S. M., & Larson, E. B. (2008). Central auditory dysfunction in older persons with memory impairment or Alzheimer dementia. *Archives of Otolaryngology Head and Neck Surgery*, 134(7), 771–777. doi:10.1001/archotol.134.7.771

Gathercole, S., & Pickering, S. (2001). Working memory deficits in children with special educational needs. *British Journal of Special Education, 28*, 89–96. doi.10.1348/000709900158047

Ghasemy, H., Momtazpour, M., & Sardouie, S. H. (2019). Detection of sustained auditory attention in students with visual impairment. *2019 27th Iranian Conference on Electrical Engineering (ICEE)*, 1798–1801. https://doi.org/10.1109/IranianCEE.2019.8786565

Goodwin, C. J., & Goodwin, K. A. (2013). *Research in psychology: Methods and design* (7th ed.). Wiley.

Haas, J. P. (2012). Sample size and power. *American Journal of Infection Control, 40*(8), 766–767. doi:10.1016/j.ajic.2012.05.020

Häggström, J., Rosenhall, U., Hederstierna, C., Östberg, P., & Idrizbegovic. E. (2018). A longitudinal study of peripheral and central auditory function in Alzheimer's disease and in mild cognitive impairment. *Dementia and Geriatric Cognitive Disorders Extra, 8*(3), 393–401. https://doi.org/10.1159/000493340

Haider, F., de la Fuente, S., & Luz, S. (2020). An assessment of paralinguistic acoustic features for detection of Alzheimer's Dementia in spontaneous speech. *IEEE Journal of Selected Topics in Signal Processing, Selected Topics in Signal Processing, IEEE Journal of, IEEE, 14*(2), 272–281. https://doi.org/10.1109/JSTSP.2019.2955022

Hancock, G. R., & Mueller, R. O. (2010). *The reviewer's guide to quantitative methods in the social sciences*. Routledge.

Harris K. M. (2010). An integrative approach to health. *Demography, 47*(1), 1–22. https://doi.org/10.1353/dem.0.0091

Hartley, D., & Priestley, J. (1775). *Hartley's theory of the human mind*. HardPress Publishing.

Hemmy, L. S., Linskens, E. J., Silverman, P. C., Miller, M. A., Talley, K. M. C., Taylor, B. C., Ouellette, J. M., Greer, N. L., Wilt, T. J., Butler, M., & Fink, H. A. (2020). Brief cognitive tests for distinguishing clinical Alzheimer-type dementia from mild cognitive impairment or normal cognition in older adults with suspected cognitive impairment. *Annals of Internal Medicine*, *172*(10), 678–687. https://doi.org/10.7326/M19-3889

Hendriks, S., Peetoom, K., Bakker, C., Filer, W., Papma, J., Koopmans, R., Verhey, F., Vugt, M., & Köhler, S. (2021). Global prevalence of young-onset dementia: A systematic review and meta-analysis. *JAMA Neurology*, *78*(9), 1080–1090. doi:10.1001/jamaneurol. 2021.2161

Hoe, J., & Hoare, Z. (2012). Understanding quantitative research: Part 1. *Nursing Standard*, *27*(15–17), 52.

Hsieh, S., Schubert, S., Hoon, C., Mioshi, E., & Hodges, J. R. (2013). Validation of the Addenbrooke's Cognitive Examination III in frontotemporal dementia and Alzheimer's disease. *Dementia and Geriatric Cognitive Disorders*, *36*, 242–250. doi:10.1159/000351671

Hu, Y., & Plonsky, L. (2021). *Statistical assumptions in L2 research: A systematic review*. Sage. https://doi.org/10.1177/0267658319877433

Iliadou, V., & Iakovides, S. (2003). Contribution of psychoacoustics and neuroaudiology in revealing correlation of mental disorders with central auditory processing disorders. *Annals of General Hospital Psychiatry*, *2*(1), 5. doi.10.1186/1475-2832-2-5

Iliadou, V., & Kaprinis, S. (2003). Clinical psychoacoustics in Alzheimer's disease central auditory processing disorders and speech deterioration. *Annals of General Hospital Psychiatry, 2*, 12 (2003). https://doi.org/10.1186/1475-2832-2-12

Indrani, T., Elisabeth, M. V., & James, B. H. (2015). The interchangeability of CVLT-II and WMS-IV verbal paired associates scores: A slightly different story. *Archives of Clinical Neuropsychology, 3*, 248. https://doi.org/ 10.1093/arclin/acv010

Jalaei, B., Valadbeigi, A., Panahi, R., Nahrani, M. H., Arefi, H. N., Zia, M., & Ranjbar, N. (2019). Central auditory processing tests as diagnostic tools for the early identification of elderly individuals with mild cognitive impairment. *Journal of Audiology and Otology, 23*(2), 83–88. http://doi.org/10.7874/jao.2018.00283

Jayakody, D. M. P., Tarawneh, H. Y., Menegola, H. K., Yiannos, J. M., Friedland, P. L., Wilson, W. J., Martins, R. N., & Sohrabi, H. R. (2020). Systematic review protocol for assessing central auditory functions of Alzheimer's disease and its preclinical stages. *BMJ Open, 10*(6), 1. doi:10.1136/bmjopen-2019-033342

Johnson, J. K., & Chow, M. L. (2015). Hearing and music in dementia. *Handbook of clinical neurology, 129* (pp. 667-687). doi:10.1016/B978-0-444-62630-1.00037-8. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4809670/

Jones Lister, J., Harrison Bush, A., & O'Brien, J. (2019). Recognizing cognitive impairment during hearing care. *ASHA Leader, 24*(7), 20. doi:10.1044/leader. AEA.24072019.20

Kamourieh, S., Braga, R. M., Leech, R., Mehta, A., & Wise, R. J. S. (2018). Speech registration in symptomatic memory impairment. *Frontiers in Aging Neuroscience, 10*. https://doi.org/10.3389/fnagi.2018.00201

Karzmark, P., & Deutsch, G. K. (2018). Accuracy statistics in predicting Independent Activities of Daily Living (IADL) capacity with comprehensive and brief neuropsychological test batteries. *Applied Neuropsychology: Adult, 25*(3), 249–257. https://doi.org/10.1080/ 23279095.2017.1286347

Keith, R. W. (1994). *SCAN-A: A test for auditory processing disorders in adolescents and adults*. https://search-ebscohost-com.ezp.waldenulibrary. org/login.aspx?direct=true&db=mmt&AN=test.392&site=eds-live&scope=site

Kim, H. (2019). Statistical notes for clinical researchers: The independent samples t-test. *Restorative Dentistry and Endodontics*, *44*(3), e26-e26. https://doi.org/10.5395/rde. 2019.44.e26

Knickman, J. R., & Snell, E. K. (2002). The 2030 problem: Caring for aging baby boomers. *Health Services Research*, *37*(4), 849–884. https://doi.org/10.1034/j.1600-0560.2002.56.x

Koran, J. (2016). Preliminary proactive sample size determination for confirmatory factor analysis models. *Measurement and Evaluation in Counseling and Development*, *49*(4), 296–308. doi:10.1177/0748175616664012

Kulijewicz-Nawrot, M., Verkhratsky, A., Chvátal, A., Syková, E., & Rodríguez, J. J. (2012). Astrocytic cytoskeletal atrophy in the medial prefrontal cortex of a triple transgenic mouse model of Alzheimer's disease. *Journal of Anatomy, 221*(3), 252–262. https://doi.org/10.1111/j.1469-7580.2012.01536.x

Kumar, S., Joseph, S., Gander, P. E., Barascud, N., Halpern, A. R., & Griffiths, T. D. (n.d.). A brain system for auditory working memory. *Journal of Neuroscience*, *36*(16), 4492–4505. https://doi.org/10.1523/JNEUROSCI. 4341-14.2016

Kvello-Alme, M., Bråthen, G., White, L. R., & Sando, S. B. (2019). The prevalence and subtypes of young onset dementia in central Norway: A population-based study. *Journal of Alzheimer's disease: JAD, 69*(2), 479–487. https://doi.org/10.3233/JAD-181223

Lang, L., Clifford, A., Wei, L., Zhang, D., Leung, D., Augustine, G., Danat, I. M., Zhou, W., Copeland, J. R., Anstey, K. J., & Chen, R. (2017). Prevalence and determinants of undetected dementia in the community: A systematic literature review and a meta-analysis. *BMJ open, 7*(2), e011146. https://doi.org/10.1136/bmjopen-2016-011146

Larner, A. J. (2007). DemTect: 1-year experience of a neuropsychological screening test for dementia. *Age and Ageing, 36*(3), 326–327. doi:10.1093/ageing/afl183

Leavy, P. (2017). *Research design: Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches*. Guilford.

Le Bouc, R., Lenfant, P., Delbeuck, X., Ravasi, L., Lebert, F., Semah, F., & Pasquier, F. (2012). My belief or yours? Differential theory of mind deficits in frontotemporal dementia and Alzheimer's disease. *Brain: A Journal of Neurology, 135*(10), 3026–3038. https://doi.org/10.1093/brain/aws237

Leedy, P. D., & Ormrod, J. E. (2012). *Practical research: Planning and design* (10th ed.). Pearson.

Leifer, B. P. (2003). Early diagnosis of Alzheimer's disease: Clinical and economic benefits. *Journal of the American Geriatrics Society, 51 Suppl 5*, S281–S288. doi:10.1046/j.1532-54155153.x

Little, L. (2003). Maternal perceptions of the importance of needs and resources for children with Asperger's syndrome and non-verbal learning disorders. *Focus on Autism and Other Developmental Disorders, 4,* 257-266. https://doi.org/10.1177/10883576030180040701

Los Angeles County Department of Public Health, Office of Health Assessment & Epidemiology (2008). *Alzheimer's disease: An emerging public health concern* [PDF]. http://publichealth.lacounty.gov/aging/docs/LA%20Health%20Alzheimer%20Disease%20Report.pdf

Lovett, B. J., & Johnson, T. L. (2011). The impact of presentation level on SCAN-A test performance. *Contemporary Issues in Communication Science and Disorders, 38,* 135–139. https://doi.org/10.1044/cicsd_38_F_135

Lowndes, G. J., Saling, M. M., Ames, D., Chiu, E., Gonzalez, L. M., & Savage, G. R. (2008). Recall and recognition of verbal paired associates in early Alzheimer's disease. *Journal of the International Neuropsychological Society, 14*(4), 591–600. https://doi.org/10.1017/S1355617708080806

Lumpkin, J. C. M., & Sheerin, C. M. (2019). Digit span sequencing as a neurocognitive screening tool in an aging, veteran population. *Psychology and Neuroscience, 12*(2), 180–190. https://doi.org/10.1037/pne0000140.supp (Supplemental)

Marschark, M., Edwards, L., Peterson, C., Crowe, K., & Walton, D. (2019). Understanding theory of mind in deaf and hearing college students. *Journal of Deaf Studies and Deaf Education, 24*(2), 104–118. https://doi.org/10.1093/deafed/eny039

Martínez-Mesa, J., González-Chica, D. A., Duquia, R. P., Bonamigo, R. R., & Bastos, J. L. (2016). Sampling: How to select participants in my research study. *Anais Brasileiros de Dermatologia, 91*(3), 326–330. https://doi.org/10.1590/abd1806-4841.20165254

Menard, S. (2002). *Applied logistic regression analysis.* Sage.Mitchell, M., & Jolley, J. (2004). *Research design explained*. Wadsworth/Thompson Learning.

Moreau, N., Rauzy, S., Viallet, F., & Champagne-Lavau, M. (2016). Theory of mind in Alzheimer's disease: Evidence of authentic impairment during social interaction. *Neuropsychology, 30*(3), 312–321. https://doi.org/10.1037/neu0000220

Nasreddine, Z. S. et al. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society, 53*, 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Nimon, K., & Reio Jr, T. G. (2011). Regression commonality analysis: A technique for quantitative theory building. *Human Resource Development Review, 10*(3), 329–340.

O'Dwyer, L. M., & Bernauer, J. A. (2017) Research in the qualitative tradition and connextions to the quantitative tradition. In *Quantitative research for the qualitative researcher*. Sage. https://doi.org/10.4135/9781506335674.n2

Perri, R., Turchetta, C. S., Caruso, G., Fadda, L., Caltagirone, C., & Carlesimo, G. A. (2018). Neuropsychological correlates of cognitive, emotional-affective and auto-activation apathy in Alzheimer's disease. *Neuropsychologia, 118*(Part B), 12–21. https://doi.org/10.1016/j.neuropsychologia.2018.01.039

Pike, K. E., Kinsella, G. J., Ong, B., Mullaly, E., Rand, E., Storey, E., Ames, D., Saling, M., Clare, L., & Parsons, S. (2013). Is the WMS-IV Verbal Paired Associates as effective as other memory tasks in discriminating amnestic mild cognitive impairment from normal aging? *Clinical Neuropsychologist, 27*(6), 908–923. https://doi.org/10.1080/13854046.2013.809149

Pituch, K. A., & Stevens, J. P. (2015). *Applied multivariate statistics for the social sciences.* Routledge.

Priestley, J. (1790). A view of the doctrine of philosophical necessity. In J. Johnson (Ed.), *Hartley's theory of the human mind, on the principle of the association of ideas; with essays relating to the subject of it* (2nd ed.) (pp. 334–367). https://doi.org/10.1037/11743-011

Putcha, D., Brickhouse, M., Wolk, D. A., & Dickerson, B. C. (2019). Fractionating the Rey Auditory Verbal Learning Test: Distinct roles of large-scale cortical networks in prodromal Alzheimer's disease. *Neuropsychologia, 129*, 83–92. https://doi.org/10.1016/j.neuropsychologia.2019.03.015

Pye, A., Charalambous, A. P., Leroi, I., Thodi, C., & Dawes, P. (2017). Screening tools for the identification of dementia for adults with age-related acquired hearing or vision impairment: A scoping review. *International Psychogeriatrics, 29*(11), 1771–1784. https://doi.org/10.1017/S104161021700120X

Ranasinghe, K. G., Kothare, H., Kort, N., Hinkley, L. B., Beagle, A. J., Mizuiri, D., Honma, S. M., Lee, R., Miller, B. L., Gorno-Tempini, M. L., Vossel, K. A., Houde, J. F., & Nagarajan, S. S. (2019). Neural correlates of abnormal auditory

feedback processing during speech production in Alzheimer's disease. *Scientific Reports, 9*(1). doi:10.1038/s41598-019041794-x

Rasmussen, J., & Langerman, H. (2019). Alzheimer's Disease—Why we need early diagnosis. *Degenerative Neurological and Neuromuscular Disease, 9*, 123–130. https://doi.org/10.2147/DNND.S228939

Rath, J. F., Hradil, A. L., Litke, D. R., & Diller, L. (2011). Clinical applications of problem-solving research in neuropsychological rehabilitation: Addressing the subjective experience of cognitive deficits in outpatients with acquired brain injury. *Rehabilitation Psychology, 56*(4), 320–328. doi:10.1037/a0025817

Reitan, R. M., & Wolfson, D. (1985). *The Halstead-Reitan Neuropsychological Test Battery: Theory and clinical interpretation*. Neuropsychology Press.

Richardson, J. T. E. (2007). Measures of short-term memory: A historical review. *Cortex, 43*(5), 635–650. https://doi.org/10.1016/S0010-9452(08)70493-3

Rodríguez-Aranda, C., Waterloo, K., Johnsen, S. H., Eldevik, P., Sparr, S., Wikran, G. C., … Vangberg, T. R. (2016). Neuroanatomical correlates of verbal fluency in early Alzheimer's disease and normal aging. *Brain and Language, 155-156*, 24–35. https://doi.org/10.1016/j.bandl.2016.03.001

Rohrer, R., Knight, W., Warren, J., Fox, N., Rossor, M., & Warren, J. (2008). Word-finding difficulty: A clinical analysis of the progressive aphasias. *Brain, 1*, 8. https://search-ebscohost-com.ezp.waldenulibrary.org/login.aspx?direct=true&db=edsovi&AN=edsovi.00002423.200801000.00004&site=eds-live&scope=site

Ross, S. R., Putnam, S. H., Millis, S. R., Adams, K. M., & Krukowski, R. A. (2006). Detecting insufficient effort using the Seashore Rhythm and Speech-Sounds

Perception Tests in head injury. *The Clinical Neuropsychologist, 20*(4), 798–815. https://doi.org/10.1080/13854040500328477

Rottman, B. M., & Hastie, R. (2014). Reasoning about causal relationships: Inferences on causal networks. *Psychological Bulletin, 140*(1), 109–139. https://doi.org/10.1037/a0031903

Sammer, G., & Lenz, E. (2020). The Montreal Cognitive Assessment (MOCA) and brain structure. *GeroPsych: The Journal of Gerontopsychology and Geriatric Psychiatry*. https://doi.org/10.1024/1662-9647/a000226

Sampath, D., Sathyanesan, M., & Newton, S. S. (2017). Cognitive dysfunction in major depression and Alzheimer's disease is associated with hippocampal-prefrontal cortex dysconnectivity. *Neuropsychiatric Disease and Treatment, 13*, 1509–1519. https://doi.org/10.2147/NDT.S136122

Seashore, C. E. (1915, May). The measurement of musical talent. *The Musical Quarterly, 1*(1), 129–148. https://www.jstor.org/stable/738047

Sedgwick, P. (2015, April). A comparison of parametric and non-parametric statistical tests. *British Medical Journal, 350*(171), h2053–h2053. doi:10.1136/bmj.h2053

Shadish, W. R., & Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference.* Houghton, Mifflin.

Sidiras, C., Iliadou, V. V., Nimatoudis, I., Grube, M., Griffiths, T., & Bamiou, D.-E. (2019). Deficits in auditory rhythm perception in children with auditory processing disorder are unrelated to attention. *Frontiers in Neuroscience*. https://doi.org/10.3389/fnins.2019.00953

Small, G. W. (2002). What we need to know about age-related memory loss. *British Medical Journal (Clinical Research Ed.), 324*(7352), 1502–1505. doi:10.1136/bmj.324.7352.1502

Soble, J. R., Bain, K. M., Bailey, K. C., Kirton, J. W., Marceaux, J. C., Critchfield, E. A., McCoy, K. J. M., & O'Rourke, J. J. F. (2019). Evaluating the accuracy of the Wechsler Memory Scale-Fourth Edition (WMS-IV) logical memory embedded validity index for detecting invalid test performance. *Applied Neuropsychology: Adult, 26*(4), 311–318. https://doi.org/10.1080/23279095.2017.1418744

Spencer, R. J., Axelrod, B., Drag, L. L., Waldron-Perrine, B., Pangilinan, P. H., & Bieliauskas, L. A. (2013, October). WAIS-IV Reliable Digit Span is no more accurate than age corrected scaled score as an indicator of invalid performance in a veteran sample undergoing evaluation for mTBI. *The Clinical Neuropsychologist, 27*(8). doi:10.1080/13854046.2013.845248

Suen, L. W., Huang, H., & Lee, H. (2014). A comparison of convenience sampling and purposive sampling. *Journal of Nursing, 61*(3), 105–111. https://doi.org/10.6224/JN.61.3.105

Sweeney, J. E. (1999). Raw, demographically altered, and composite Halstead-Reitan Battery Data in the evaluation of adult victims of nonimpact acceleration forces in motor vehicle accidents. *Applied Neuropsychology, 6*(2), 79. https://doi.org/10.1207/s15324826an0602_3

Tharenou, P., Saks, A. M., & Moore, C. (2007, September). A review and critique of research on training and organization level outcomes. *Human Resource Management Review, 17*(3), 251–273. doi:10.1016/j.hrmr.2007.07.004

Thursina, C., Harahap, I. S. K., Sadewa, A. H., & Hapsara, S. (2017, October). The difference type and disease severity in a family with spinal muscular atrophy (SMA). *Journal of the Neurological Sciences, 381*, 279. doi:10.1016/j.ins.2017.08.796

Tsoi, K. K. F., Chan, J. Y. C., Hirai, H. W., Wong, S. Y. S., & Kwok, T. C. Y. (2015). Cognitive tests to detect dementia: A systematic review and meta-analysis. *JAMA Internal Medicine*, 175, 1–9. doi:10.1001/jamainternmed.2015.2152

Tsoi, K. K. F., Slattery, C. F., Agustus, J. L., Paterson, R. W., McCallion, O., Foulkes, A. J. M., Macpherson, K., Carton, A. M., Harding, E., Golden, H. L., Jaisin, K., Mummery, C. J., Schott, J. M., & Warren, J. D. (2019). The functional neuroanatomy of musical memory in Alzheimer's disease. *Cortex, 115*, 357–370. https://doi.org/10.1016/j.cortex.2019.02.003

Tulsky, D. H. Saklofske, G. J., Chelune, R. K., Heaton, R. J., Ivnik, A., Prifitera, M., Ledbetter, F., & Bornstein, R. (2003). *Clinical interpretation of the WAIS-III and WMS-III*. Academic Press.

Tuwaig, M., Savard, M., Jutras, B., Poirier, J., Collins, L. D., Rosa-Neto, P., Fontaine, D., & Breitner, J. (2017). Deficit in central auditory processing as a biomarker of pre-clinical Alzheimer's disease. *Journal of Alzheimer's Disease, 60*(4), 1589–1600. https://doi.org/10.3233/JAD-170545

Wankerl, S., Noeth, E., & Evert, S. (2017). An N-gram based approach to the automatic diagnosis of Alzheimer's disease from spoken language. 10.21437/Interspeech. 2017–1572. http://www.stefan-evert.de/PUB/WankerlNoeth Evert2017.pdf

Weakliem, D. (2016). *Hypothesis testing and model selection in the social sciences.* Guilford.

Webber, T. A., & Soble, J. R. (2018). Utility of various WAIS-IV Digit Span indices for identifying noncredible performance validity among cognitively impaired and unimpaired examinees. *Clinical Neuropsychologist, 32*(4), 657–670. https://doi.org/10.1080/13854046.2017.1415374

Wechsler, D. (2008). *WAIS-IV: Wechsler adult intelligence scale.* The Psychological Corporation.

Wechsler, D. (2009). *Wechsler Memory Scales—Fourth Edition (WMS-IV*): *Administration and scoring manual.* Pearson Clinical Assessment.

Whitley, B. E., Kite, M. E., & Adams, H. L. (2013). *Principles of research in behavioral science* (3rd ed.). Psychology Press.

Wisniewski, M. (2016). *Quantitative methods for decision makers* (6th ed.). Pearson.

Zenisek, R., Millis, S. R., Banks, S. J., & Miller, J. B. (2016, August). Prevalence of below-criterion Reliable Digit Span scores in a clinical sample of older adults. *Archives of Clinical Neuropsychology, 31*(5), 426–433. https://doi.org/10.1093/arclin/acw025

Zheng, Y., Fan, S., Liao, W., Fang, W., Xiao, S., & Liu, J. (2017). Hearing impairment and risk of Alzheimer's disease: A meta-analysis of prospective cohort studies. *Neurological Sciences, 38*(2), 233–239. https://doi.org/10.1007/s10072-016-2779-3