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Validity of GrayMatters: A Self-Administered Computerized Assessment of Alzheimer's Disease

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ABSTRACT

The need for early detection of Alzheimer's disease has been well established in previous literature. As technology has spread across all professional fields, computerized screening instruments for the early detection of Alzheimer's disease have begun to draw attention. Research has noted that computerized screeners of dementia should be implemented in primary care physician offices, as the majority of elderly persons see their PCP more frequently than other health professionals. Specifically, self-administered computerized screening instruments that have acceptable psychometric sturdiness are needed for these offices. GrayMatters is a self-administered computerized screening measure that has previously been shown to have acceptable reliability and validity. The aim of this study was to reevaluate the concurrent validity of GrayMatters. Reevaluation was needed in order to compare GrayMatters to the Wechsler Memory Scale-IV, rather than the Wechsler Memory Scale-III as previous research had done, and due to population changes over time. In order to evaluate the concurrent validity of GrayMatters, archival data from 149 female participants and 102 male participants was gathered from the Texas Neuropsychology Clinic. Data sets included participants GrayMatters scores, Wechsler Memory Scale-IV scores, Mini-Mental Status Examination scores, Trailmaking A and B scores, Boston Verbal Fluency Test scores, as well as the participant's age, gender, race, and level of education. GrayMatters scores were compared to scores from the WMS-IV, MMSE, Trailmaking A and B, and Boston Verbal Fluency Test in order to examine concurrent validity. Results indicate that GrayMatters scores were compatible with scores

from all previously mentioned measures. These findings are important because they indicate that GrayMatters can be used as a screening instrument of Alzheimer's disease that can be used to measure cognitive impairment and guide decisions regarding patient care.

Validity of GrayMatters:

A Self-Administered Computerized Assessment of Alzheimer's Disease

A Thesis

Presented to

The Faculty of the Department of Psychology

Abilene Christian University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science

By

Emily C. Hicks

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CHAPTER I

INTRODUCTION

As the elderly population increases rapidly worldwide, Alzheimer's disease has become a primary health care concern, impacting more than 5.5 million elderly Americans. Alzheimer's disease is the sixth leading cause of death in the United States and is thought to be the third leading cause of death in the elderly (National Institute on Aging [NIA], 2017a). The rates of Alzheimer's disease have grown substantially, and 16 million Americans are expected to be impacted by 2050 (U.S. Department of Health and Human Services [DHHS], 2013). Alzheimer's disease leads to an inability to carry out activities of daily living, difficulty with word finding, impaired judgment, and deficits in cognitive functioning (NIA, 2017b). Individuals with Alzheimer's disease may live anywhere between three to ten or more years after diagnosis depending on factors such as age at diagnosis and treatment received (NIA, 2017a), but ultimately, Alzheimer's disease is fatal. Early diagnosis of Alzheimer's disease is critical, as it allows the patient to explore treatment options and begin treatment earlier. Unfortunately, many individuals suffering from memory loss do not seek out early neuropsychological evaluation; however, elderly individuals often schedule appointments with their primary care physician (PCP). Thus, dementia screening by the PCP is arguably the preferred option. The need to develop and implement valid, short dementia screening tests in PCP offices is fundamental to the early recognition and treatment of Alzheimer's disease.

Diagnosis of Alzheimer's disease

The majority of individuals diagnosed with Alzheimer's disease (AD) are diagnosed through a neuropsychological evaluation. A probable Alzheimer's disease diagnosis can be established with 90% confidence through the utilization of medical history, laboratory tests, and neuropsychological evaluation (Humpel, 2011). Unfortunately, neuropsychological evaluation is costly, time-consuming, and potentially frustrating for the patient. Neuropsychological assessment may cost upwards of $1,000, an unfeasible amount for individuals on a fixed income and individuals with a low socioeconomic status. In spite of the complications with current diagnostic tools, Alzheimer's disease diagnosis is critical for optimal patient care.

Current Diagnostic Methods

The Wechsler Memory Scale-IV (WMS-IV) is a widely used assessment of dementia that has received significant research support. Although the WMS-IV is the most widely used adult memory assessment (Pearson Clinical, 2009) and has been proven to have diagnostic and clinical usefulness, there are several limitations in using the WMS-IV for AD diagnosis. First, the WMS-IV is costly and time intensive to administer. Second, a test examiner with a thorough amount of training is required for administration. Third, several studies have noted the importance of considering education level when diagnosing AD (Bornstein, Chelune, & Priftera, 1989; Efklides et al., 2002; Farias, Harrell, Neumann, & Houtz, 2003), which the WMS-IV does not take into consideration.

Screening instruments have been developed in order to combat the problems of cost and time-requirements associated with traditional diagnostic methods. Currently, the Mini-Mental Status Exam (MMSE) is the most widely used instrument to screen for

cognitive impairment (Brinkman et al., 2012). However, it has been shown to lack sensitivity with regards to mild cognitive impairment (Brinkman et al., 2012; Saxton et al., 2009). The Boston Verbal Fluency Test has also been used as a screening instrument for Alzheimer's disease, as it measures disruptions in semantic memory, which has been associated with Alzheimer's disease and other dementias (Maseda et al., 2014). Unfortunately, research suggests that education level impacts Boston Verbal Fluency Test scores (Maseda et al., 2014), which is not taken into consideration in administration. The use of computerized dementia screeners has been a recent focus of attention, as they provide a comprehensive assessment that combats the logistical and practical problems associated with traditional neuropsychological evaluation.

The Present Study

The present study evaluated the concurrent validity of a self-administered computerized assessment of dementia, developed by Dr. Samuel Brinkman, known as GrayMatters (Brinkman et al., 2012). To establish validity the current study compared GrayMatters to the WMS-IV, Trailmaking parts A and B, Boston Verbal Fluency Test, and the Mini-Mental Status Examination. Although GrayMatters has previously been shown to be a valid dementia screening measure (Brinkman et al., 2012), the present study sought to reevaluate validity for several reasons. First, the GrayMatters system needed to be validated in comparison to the Wechsler Memory Scale-IV, rather than the Wechsler Memory Scale-III. Second, as with the majority of scientific research, the current literature regarding the GrayMatters system derives from researchers who were involved in the construction of the test. The validity of GrayMatters was assessed by persons other than the test designer in the present study. Lastly, research also notes that

validity should be evaluated in matters of degrees, instead of absolute terms, so assessments must be reevaluated as the population changes over time (Bauer et al., 2012; Nunnally & Bernstein, 1994).

The present work has implications for neuropsychologists, PCPs, and AD patients. Valid, short dementia screening measures are beneficial for both practitioners and patients as they save time, energy, and money by helping guide decision making as to who should seek in-depth neuropsychological evaluation. They may also provide care for typically underserved populations, as they are an option for individuals without insurance, have conservative costs, involve short administration times, and produce immediate results. Finally, results of this study may have important implications for future research. If patient's attitudes towards dementia assessment in a PCP's office versus a neuropsychology clinic were researched, the impact of patient setting preference on test scores could be explored. Examining the patient's experience of dementia screening may help to guide decisions regarding optimal patient care.

CHAPTER II

LITERATURE REVIEW

Alzheimer's disease (AD) is an irreversible, progressive brain disorder that destroys brain cells, leading to a loss of memory and other brain functions (NIA, 2017b; U.S. Department of Health and Human Services [DHHS], 2013). Ultimately, AD is fatal. Problems with memory are generally the first sign of AD, but significant decline in other areas of cognitive functioning are also evident. AD is associated with visual-spatial issues, difficulty with word finding, and impaired judgment (NIA, 2017b). Eventually, AD leads to the inability to carry out daily tasks such as driving, cooking, and paying bills (NIA, 2017b). As the disease progresses, individuals may become anxious, worried, or violent.

It is estimated that 5.5 million Americans aged 65 and older have Alzheimer's disease, though many more individuals under the age of 65 also have the disease (DHHS, 2013; NIA, 2017a). The number of AD cases is expected to climb significantly as the population continues to see a sharp increase in elderly individuals. The heightened rates of AD not only have negative effects on patients and caretakers, but also on communities and the economy (Brinkman et al., 2012). According to the Alzheimer's Association, the cost of care for patients with AD in the United States in 2018 was $277 billion (2018). Over the next 40 years, caring for individuals with AD will cost taxpayers $20 trillion (DHHS, 2013). The extraordinary costs related to AD stem from payment for caretaker and living facilities, insurance coverage, and the high rates of co-occurrence of AD and

various diseases (DHHS, 2013). Americans are in dire need of solutions to aid AD patients, caretakers, and the U.S. economy.

Diagnosis of Alzheimer's disease

AD was officially recognized as a disease in 1984, but the AD diagnostic criteria were updated in 2011. The 2011 guidelines recognized that AD occurs on a spectrum with three stages: a preclinical stage with no symptoms, a middle stage consisting of mild cognitive impairment, and a final stage marked by dementia symptoms (Jack et al., 2011). The revised diagnostic criteria also demonstrated that AD is more than a memory disorder and includes symptoms such as impaired word-finding ability and judgment (NIA, 2017b). One notable difference from the 1984 diagnostic criteria was the inclusion of biomarkers as indicators of underlying brain disease (Jack et al., 2011; NIA, 2017b). Biomarkers are "parameters (physiological, biochemical, anatomic) that can be measured in vivo and that reflect specific features of disease related pathophysiological processes" (Jack et al., 2011, p. 260). Key AD biomarkers include the buildup of β-amyloid protein in plaques and tau disposition in neurofibrillary tangles (Jack et al., 2011). Though the recognition of biomarkers has greatly enhanced the discovery and diagnosis of AD, the disease still cannot be truly diagnosed until autopsy (Mantzavinos & Alexiou, 2017; NIA, 2017b).

Difficulty with AD Diagnosis

Biomarkers have improved AD research and diagnosis, but recognition of biomarkers in individuals is not always a feasible option. The most notable issue in using biomarkers for diagnosis is that established biomarkers of AD are found in cerebrospinal fluid (Humpel, 2011). In order to evaluate an individual's biomarkers, he or she must

undergo lumbar puncture and collection of cerebrospinal fluid, which is painful for the individual and may lead to adverse side effects (Humpel, 2011). A further problem with the use of biomarkers as a diagnostic tool is that biomarkers have been primarily studied in Caucasian populations, and research is needed in diverse populations (Dubois, Padovani, Scheltens, Rossi, & Dell'Agnello, 2016; Jack et al., 2017). Currently, biomarkers are employed in research, but not in clinical care (Sullivan, 2018).

Neuropsychological evaluation is effective for diagnosing probable Alzheimer's disease, but is costly, time-consuming, and potentially frustrating for the patient. A detailed neuropsychological assessment may take up to eight hours to complete when the assessment includes a thorough diagnostic interview and full neuropsychological test battery (University of North Carolina Department of Neurology, n.d.). The amount of time required to complete a neuropsychological assessment may be difficult for the individual due confusion, stress, and fatigue induced by testing. Evaluations are also costly, which is a source of concern for many patients. Individuals who reside in rural areas may be unable to obtain neuropsychological assessments, as professionals who are qualified to administer tests typically reside in urban areas. Professionals who are administering the assessment may also experience difficulty in gathering an accurate medical history from patients with memory deficits. In spite of the current complications with existing diagnostic tools, diagnosis of AD is critical for patient well-being. Specifically, early diagnosis is critical for AD patients to reap the greatest benefits from treatment.

Benefits of Early Diagnosis

The advantages of early diagnosis of Alzheimer's disease are numerous. Benefits may be emotional and interpersonal, medical, or financial (Boller & Barba, 2001; Brinkman et al., 2012; Fillit, H.M., Simon, E.S., Doniger, G.M., & Cummings, J.L., 2008; Lees et al., 2014; Weimer & Sager, 2009). Individuals are first given a diagnosis of "probable AD" when they begin to show signs of mild cognitive impairment (Sullivan, 2018). During this stage of AD, the individual may still function independently and may still drive, maintain employment, and be active socially (Alzheimer's Association, 2018).

Emotional and Interpersonal Benefits

Early diagnosis allows the patient and caretakers to plan for the future while symptoms are mild, so informed decisions can be made regarding treatment options, finances, and driving ability (Makizako et al., 2013; Saxton et al., 2009). Additionally, diagnosis during this stage allows patients and their families to explore education and support programs, leading to enhanced patient and caregiver well-being. (Alzheimer's Association, 2018). Further, many patients experience a sense of relief following diagnosis. The majority of individuals with mild cognitive impairment recognize that they are having difficulty with memory, and as a result, the explanation of symptoms and presentation of a treatment plan may provide relief in many AD cases (Carpenter et al., 2008; Portacolone, Johnson, Covinsky, Halpern, & Rubinstein, 2018).

Medical Benefits

When an individual receives an early diagnosis of AD, he or she can implement various health behaviors to maintain their current level of cognitive functioning for a greater amount of time. For example, control of blood pressure, control of diabetes, and

smoking cessation will help to decrease the likelihood of a stroke, which leads to the progression of AD symptoms (Langa & Levine, 2014). The inclusion of aerobic exercise, mental stimulation, and social activity may also decrease the progression of cognitive decline (Langa & Levine, 2014). Unfortunately, the decline of a patient's cognitive functioning typically goes unnoticed for several years, and by the time of diagnosis and treatment, the patient is too impaired to reap the full benefits of medication (Brinkman et al., 2012; Fillit et al., 2008). Early diagnosis also allows the patient and family members to consider different treatment options and decide what will be most beneficial for the patient. Although current medications cannot prevent or reverse the onset of AD, they can temporarily prolong cognitive functioning (Epperly, Dunay, & Boice, 2017). An early AD diagnosis also enhances an individual's chances of participating in a clinical trial. Participating in trials with novel treatments may allow the patient to experience health benefits, often at no cost, while receiving high quality care, monitoring of symptoms, and education regarding AD (Alzheimer's Association, 2011). Psychological benefits may occur from the knowledge that one is contributing to important research, even if novel medication proves ineffective for the patient (Alzheimer's Association, 2018).

Financial Benefits

Early diagnosis of AD may result in reduction of health care costs both for the individual and for the national economy (Alzheimer's Association, 2018). It is expected that the United States will spend more than $1.3 trillion in AD research and treatment by 2050, but early diagnosis may alleviate some of the expense (Alzheimer's Association, 2018; Sullivan, 2018). If 88% of AD cases were diagnosed when they first began

showing signs of mild cognitive impairment, the US would save $231.4 billion in treatment and long-term care (Alzheimer's Association, 2018; Sullivan, 2018). Savings would result from reduced Medicare and Medicaid expenditures, out-of-pocket expenses, and private insurance expenses (Alzheimer's Association, 2018; Sullivan, 2018). Early diagnosis would aid in the savings through financial planning, early treatment options, and implementation of beneficial health behaviors.

Current Diagnostic Methods

WMS-IV

The WMS-IV consists of seven primary subtests that measure auditory memory, visual memory, visual working memory, immediate memory, and delayed memory (Pearson Clinical, 2009). The delayed memory index has proven to be especially useful in aiding with AD diagnosis (Borstein, Priftera, & Chelune, 1989). Research has noted that individuals diagnosed with AD perform significantly worse on the WMS-IV than healthy individuals (Efklides et al., 2002). Specifically, AD patients had lower scores in subtests measuring semantic memory, orientation, visual recognition, and new learning, which is consistent with current research on AD (Efklides et al., 2002). The WMS-IV has also been shown to have clinical utility in predicting AD patients' ability to carry out activities of daily living (Farias et al., 2003). Individuals who received lower scores on the Logical Memory and Digit Span subtests of the WMS-IV were found to have greater difficulty in performing activities of daily living independently (Farias et al., 2003).

Screeners

The Mini-Mental Status Exam (MMSE) is the most widely used screening instrument but has been shown to lack sensitivity with regards to mild cognitive

impairment (MCI) (Brinkman et al., 2012; Saxton et al., 2009). Research indicates that the sensitivity of the MMSE in detecting individuals with MCI who may progress to AD ranges from 27% (Buchave et al., 2008) to 89% (Arevelo-Rodriguez et al., 2015; Devanand et al., 2008). The specificity of the MMSE in detecting the progression of MCI to AD ranged from 32% (Buchave et al., 2008) to 90% (Arevelo-Rodriguez et al., 2015; Devanand et al., 2008). One study found that the MMSE was only able to correctly identify 54% of patients with MCI, and the MMSE also demonstrated ceiling effects (Hoops et al., 2009). The highly variable sensitivity and specificity of the MMSE indicate that a more consistent dementia screening instrument is needed.

The Boston Verbal Fluency Test has also been used as a screener for dementia. It has been shown to have a sensitivity of 78% when discriminating between healthy adults and adults with mild dementia (Gomez & White, 2006), but doesn't consider the patient's education level. Disruptions in semantic memory have been shown to be strongly correlated with Alzheimer's disease and other dementias (Maseda et al., 2014). Additionally, both qualitative and quantitative aspects of the Boston Verbal Fluency Test are considered to be important in understanding the deteriorated cognitive processes of dementia patients; however, examining qualitative components of the Boston Verbal Fluency Test is subjective and time-consuming (Gomez & White, 2006).

Computerized tests have been developed to combat the problems with traditional dementia screening measures. (Ahn et al., 2010; Bauer et al., 2012; Dougherty et al., 2010; Fowler, Saling, Conway, Semple, & Louis, 1997; Inoue, Jinbo, Nakamura, Taniguchi, & Urakami, 2009). Measures such as the Computerized Assessment of Mild Cognitive Impairment (Saxton et al., 2009), Mindstreams (Fillit et al., 2008), the

Computerized Self-Test (Doughtery et al., 2010), the Cognitive Assessment of Later Life Status (Zygouris & Tsolaki, 2014) and Cleveland Clinic Computerized Cognitive Battery (Rao, 2018) have been developed specifically for use by elderly persons. The aim of these computerized tests is to provide a comprehensive assessment that combats the logistical and practical problems associated with traditional neuropsychological assessment (Fillit et al., 2008). Computerized dementia assessments should strive to be simple and rapid, but maintain adequate sensitivity and specificity (Maruff et al., 2009).

Benefits of Psychometric Diagnosis

Alzheimer's disease is primarily diagnosed through a primary care physician, neuropsychologists, geriatricians, or neurologists (National Institute on Aging [NIA], 2017b). In order to diagnose AD, the clinician may conduct a diagnostic interview, administer tests of memory and problem solving, and perform brain scans and other medical tests to rule out other possible causes for the patient's symptoms (NIA, 2017b). Extensive training and knowledge qualifications are expected of clinicians who may diagnose individuals with AD. Research indicates that for individuals to be considered competent in neuropsychology and neuropsychological assessment, he or she must have obtained graduate and professional training, have expert knowledge regarding the brain-behavior relationship, have the required skills and knowledge regarding the neuropsychological assessments they may administer, be able to competently communicate neuropsychological findings and test results, and have the knowledge and skills needed for neuropsychological intervention (Hessen et al., 2017).

The majority of elderly persons obtain their health care solely from their primary care physician (PCP) and often fail to report problems with memory, leading to over half

of dementia cases going unnoticed (Fillit et al., 2008; Saxton et al., 2009). If a system were in place to aid PCPs in the early detection of cognitive impairment, it is estimated that the number of identified dementia cases would double (Brinkman et al., 2012; Saxton et al., 2009). Including a dementia screening as part of an elderly person's routine physical examination would allow for better treatment for the patient, and better management of financial resources as only those who showed signs of impairment would be referred for lengthier, more costly neuropsychological assessment (Hammers et al., 2012; Lees et al., 2014; Rao, 2018; Zygouris & Tsolaki, 2014). Since dementia screening by the PCP is arguably the preferred option, there is an increased interest in short screening tests (Fillit et al., 2008; Zygouris & Tsolaki, 2014). Short tests are preferable as they induce less fatigue for the patient and are able to be administered repeatedly, which is important in measuring cognitive decline over time (Hammers et al., 2012; Zygouris & Tsolaki, 2014). Specifically, low-cost, self-administered screening measures designed for use in a primary care office are needed to identify individuals in the preclinical stage of dementia, where pharmacologic interventions are most effective (Rao, 2018).

Determining baseline cognitive functioning in the elderly is also important for the diagnosis of AD. Obtaining baseline data regarding an individual's cognitive abilities in the areas of memory and executive functioning is especially important in recognizing onset of dementia (Brinkman et al., 2012). Research has indicated that baseline cognitive function is predictive of AD patients' rate of decline in basic-care functioning (Atchison, Massman, & Doody, 2007). In fact, this longitudinal study discovered that concurrent neuropsychological assessment was better able to account for variance in patients' self-maintenance abilities than single measures of cognitive status (Atchison et al., 2007).

Obtaining baseline cognitive functioning scores by a PCP and repeating the assessment over time would be ideal for the recognition of cognitive decline, prediction of self-care functioning, and diagnosis of AD.

Technology in AD Diagnosis

Computerized dementia screening instruments are expected to become more widespread (Brinkman et al., 2012; Rabin et al., 2014; Wild et al., 2008). Specifically, self-administered computerized tests will increase rapidly in use as they have many cost-effective and standardization benefits (Bauer et al., 2012; Brinkman et al., 2012). Advantages of self-administered computerized measures include: ability to be administered without highly-trained staff (Bauer et al., 2012; Brinkman et al., 2012; Rabin et al., 2014), administration of complex tasks in a standardized manner (Brinkman et al., 2012; Parsey & Schmitter-Edgecombe, 2013; Rabin et al., 2014; Wild et al., 2008), automated scoring and reporting (Bauer et al., 2012; Brinkman et al., 2012; Rabin et al., 2014; Schatz & Browndyke, 2002), paperless record-keeping systems (Brinkman et al., 2012), decreased examiner influence on responses (Bauer et al., 2012; Rabin et al., 2014; Wild et al., 2008), and increased accessibility in areas where there is a lack of psychological services (Bauer et al., 2012; Rabin et al., 2014). Although some may be concerned about the feasibility of older adults using self-administered technology, research demonstrates that older adults are welcoming of and able to respond to computerized self-administered tests (Collerton et al., 2007; Fillit et al., 2008; Wild et al., 2008). Research indicates that dementia patients are accepting of technology, as long as there is minimal new learning required of them (Rosenburg, Wingard, Kottorp, & Nygard, 2012).

GrayMatters

The current study utilizes a self-administered computerized assessment of dementia known as GrayMatters (Brinkman et al., 2012). Other computerized dementia assessments have been developed and show promise, which may lead some to question the need for another assessment. However, GrayMatters differs from previously developed measures in several ways. First, research suggests that computerized self-administered measures designed to be used by elderly individuals should employ a touch-screen computer monitor in order to decrease the difficulty of interactions between the patient and the computerized test (Tornatore, 2005). GrayMatters employs a touch-screen monitor in accordance with the current research. Second, according to the American Psychological Association (1999), computerized assessments should meet the same psychometric standards as examiner-administered tests (Bauer et al., 2012); however, many computerized tests lack an empirical foundation and psychometric sturdiness (Brinkman et al., 2012; Tierney & Lermer, 2010). GrayMatters has been previously established as an empirically supported computerized assessment (Brinkman et al., 2012). Third, GrayMatters presents directions both orally and visually, and administration requires only twenty minutes. The GrayMatters system was designed to measure memory and executive functioning, which have previously been established as key domains in identifying cognitive impairment and dementia. GrayMatters consists of a Visual Delayed Recognition Task (VDR) and a Delayed Alternation Task (DAT).

Visual Delayed Recognition Task

Visual Delayed Recognition Task (VDR) was designed to measure visual memory (Brinkman et al., 2012). Research has previously established that visual memory tasks are

essential for recognizing cognitive decline and AD (Brinkman et al., 2012; Lee, 2010; Saunders & Summers, 2011). There is also some research that suggests that visual memory tasks may be more sensitive to the identification of mild cognitive impairment than verbal memory tasks (Alladi, S., Arnold, R., Mitchell, J., Nestor, P.J., & Hodges, J.R., 2006; Brinkman et al., 2012). The VDR task has a forced-choice format that measures an individual's ability to obtain and retain new visual information. Images of objects are presented on the computer screen and patients are verbally instructed to study the pictures. The images are then removed from the screen, and one picture is presented to the patient while he or she is asked, through both verbal and written cues, to choose whether the picture (challenge picture) was one of the images just presented. The patient is cued to touch either the *Yes* or *No* button as their response to the question. VDR consists of 12 total trials. The first trial has a high likelihood of the patient responding correctly, with only two images presented simultaneously for five seconds and challenge items presented after a delay of five seconds. Eleven additional sets of images are shown on the computer screen, and each of these sets has four images presented simultaneously. In these sets, two challenge pictures are presented simultaneously after a five-second delay, and the participant again responds by selecting either the *Yes* or *No* button. There are an equal number of correct and incorrect challenge items presented to the patient. Trials 5 through 8 and trials 9 through 12 are comparable in difficulty level; however, in trials 9 through 12, patients are given simple distractor tasks during the delay interval to decrease the opportunity to replay the images in their mind. The distractor tasks are also completed via the touch screen monitor on the computer. A score is derived for VDR

based on the total number of correctly identified images on challenge trials, the number of false positive errors, and the number of correct responses on distractor tasks.

Delayed Alternation Task

The Delayed Alternation Task (DAT) is a useful measure of executive functioning for computerized assessments (Brinkman et al., 2012) that was originally described by Hunter (1913). DAT is a problem-solving task with paradigm shifts. There are four tasks, each consisting of different rules, which are presented via the computer to the patient. First, a picture of two hands is shown on the monitor. The pictures of the hands are mirror images of the same hand, which ensures that the pictures are equated visually. The patient is asked to touch the hand that he or she believes a coin can be found under. After the participant responds, the hand is flipped to either show a coin or an empty hand. After a 10-second delay, which is consistent with traditional DAT paradigms, the set of hands are presented again, and the patient is again prompted visually and orally to select which hand he or she believes the coin is under. The visual cue is presented in text version on the computer screen, and the same instructions are presented in the visual and oral format. In the first task of DAT, the Delayed Alternation rule is followed which consists of the coin being placed in the opposite hand after a correct response and remaining in the same hand after an incorrect response. The response is correct on the first trial regardless of which hand the patient selected. There are 25 individual trials unless a patient responds correctly to five trials sequentially, which denotes that the patient reached the success criterion.

After 25 trials, which is the failure criterion, or reaching the success criterion, the patient begins a second task that utilizes a non-alternating rule. This rule causes the coin

to remain in the same hand during all trials. The patient's first response is again considered correct regardless of which hand is chosen. The criteria for success and failure are the same under this rule as the previous rule. The previously used delay period between trials is discontinued under this rule and all subsequent rules in order to shorten the overall assessment time, as the primary interest in these rules involves the patient's ability to shift cognitive sets after learning the first rule.

During the third task, the hands are replaced by shapes. This rule is called the Shape Alternation rule and uses a blue circle and a red square as stimuli. The patient is instructed to select which shape the coin is under. Again, the patient's first response is always correct, and the coin is switched to the opposite shape after a correct response and remains under the same shape after an incorrect response. The locations of the shapes, either left or right side of the computer monitor, vary based on a predetermined sequence. The same success and failure criteria are implemented in this rule.

The fourth and final task is the Side Alternating rule and uses the same shapes as the previous task. In this rule the coin is moved to the opposite side of the screen after a correct response and is left on the same side of the screen after an incorrect response. Again, the location of the shapes varies depending on the predetermined sequence of the 25 trials. Success and failure criterion are the same as previous rules. The scores for DAT are determined by the number of rules for which the patient meets success criteria, total number of correct responses over all four rules, and the number of perseverative errors. A perseverative error is an error on consecutive responses.

Early Psychometric Data

In an earlier psychometric study of GrayMatters, all recruited participants were able to complete the screening test, and no statistically significant differences between racial or ethnic groups were discovered (Brinkman et al., 2012). The previous research had more female than male participants, and impaired individuals were significantly older than unimpaired individuals. The education level of the impaired group was lower than the education level of the unimpaired group by 0.8 years. The analyses indicated that unimpaired participants had significantly better scores than the impaired participants in total number of correct responses in VDR, the number of false positive errors, and the number of correct responses on distractor tasks. Expected differences in the DAT section were also discovered. The VDR test-retest reliability ranged from 0.72 to 0.74 ($p<.001$) and DAT correlation coefficients ranged from 0.37 to 0.54 ($p<.001$). Correlations between the WMS-III and VDR were statistically significant. Statistically significant were also found between measures of executive functioning. The previous study did not follow up with participants to determine how many individuals were diagnosed with dementia.

Present Study

The current study will reevaluate the concurrent validity of GrayMatters. That is, the validity of GrayMatters will be established by comparing GrayMatters scores to scores of the WMS-IV, Trailmaking parts A and B, Boston Verbal Fluency Test, and the Mini-Mental Status Examination. While GrayMatters has previously been established as a reliable and valid measure (Brinkman et al., 2012), the current study will examine

validity with newer versions of measures that have been developed and with the current population.

CHAPTER III

METHODS

Participants

Data for the present study was collected through archival records from the Texas Neuropsychology Clinic in Abilene, Texas. The most recent 102 men and 148 women to have completed a neuropsychological assessment and be diagnosed with Alzheimer's disease were included in the study. This method of selecting subjects was chosen for two reasons. First, a primary goal of the present study was to validate GrayMatters with current populations, so utilizing recent data was imperative. Second, the current study sought to validate GrayMatters with both males and females, as earlier psychometric studies lacked proportionate gender participation. Permission to access the data sets was obtained through the Texas Neuropsychology Clinic, and all records remain the private record of the Clinic. The data collected from each of the participants consisted of their GrayMatters, WMS-IV, MMSE, Boston Verbal Fluency Test, and Trailmaking A and B scores. All data sets were cleansed of the subject's identity. Personal information included with the data set consisted of the subject's age, gender, and highest level of education. Data sets were cleared of any identifying information by the office manager of the Texas Neuropsychology Clinic and sent electronically to the researcher.

Measures

GrayMatters

The present study utilized GrayMatters as a self-administered computerized assessment of Alzheimer's disease. GrayMatters employs two tasks: Visual DelayedRecognition and Delayed Alternation (Brinkman et al., 2012). The two tasks measure visual memory and executive functioning (Brinkman et al., 2012). Example exercises of GrayMatters include finding a coin under a set of hands based on a pattern and viewing images and identifying them after a delay (Brinkman et al., 2012). Specific details regarding Visual Delayed Recognition and Delayed Alternation tasks can be found in the GrayMatters section of the literature review. Early psychometric studies of GrayMatters suggest test-retest reliability ranging from 0.37 (DAT Rules Correct) to 0.74 (VDR Distractor Correct), and statistically significant correlations between measures of executive functioning (Brinkman et al., 2012).

WMS-IV

The WMS-IV was included as part of the data set in the current study as it is a widely used assessment of Alzheimer's disease. The WMS-IV consists of seven primary subtests that measure auditory memory, visual memory, visual working memory, immediate memory, and delayed memory (Pearson Clinical, 2009). The WMS-IV has been found to have internal consistency ranging from 0.83-0.90 and test-retest correlations ranging from 0.50-0.73 (Pearson Clinical, 2009).

MMSE

The MMSE was included as part of the collected data as it is currently the most widely used dementia screener (Brinkman et al., 2012; Saxton, 2009). The MMSE is a

30-item questionnaire that assesses an individual's orientation to date and time, attention and calculation abilities, and capacity to follow commands (Folstein, Folstein, & McHugh, 1975). Example items include "What is the year?" and "Repeat the phrase 'No ifs, ands, or buts.'" (Folstein et al., 1975). Reported degrees of the MMSE's sensitivity and specificity have varied greatly. Early psychometric data suggested that the MMSE had both adequate reliability and validity (Folstein et al., 1975); however, more recent data has found inconsistent degrees of sensitivity and specificity (Arevelo-Rodriguez et al., 2015; Buchave et al., 2008; Devanand et al., 2008; Hoops et al., 2009).

Trailmaking A and B

The Trailmaking tests were included in the study, as they have been used extensively in neuropsychological assessment and are a measure of an individual's executive functioning (Brinkman et al., 2012). Part A of Trailmaking involves the patient drawing lines to connect circled numbers in numerical order as quickly as possible without making mistakes (Salthouse, 2011). Part B involves the patient drawing lines to connect circled numbers and circled letters while alternating numerical and alphabetical order as quickly as possible without making mistakes (Salthouse, 2011). Trailmaking test parts A and B have been shown to have high reliability with retest reliability of part A ranging from 0.76-0.89, and retest reliability of part B ranging from 0.86-0.94 (Wagner, Helmreich, Dahmen, Lieb, & Tadic, 2011).

Boston Verbal Fluency Test

The Boston Verbal Fluency Test was included as part of the data set in the current study due to research noting the importance of semantic network deterioration in the detection of Alzheimer's disease (Maseda et al., 2014). The Boston Verbal Fluency Test

involves asking a participant to name as many animals as possible in sixty seconds (Gomez & White, 2006). Although the Boston Verbal Fluency Test may be scored with both qualitative and quantitative components, only quantitative data was used in the present study. The quantitative variable of the Boston Verbal Fluency Test is scored by totaling the number of correct responses for animal that the participant is able to name in sixty seconds (Gomez & White, 2006). The sensitivity of the Boston Verbal Fluency Test in detecting dementia has ranged from 67% (Sebaldt et al., 2009) to 77% (Radanovic et al., 2008).

Hypotheses

The hypotheses guiding the statistical analyses for the present study were as follows: 1) GrayMatters Composite score will be significantly, negatively correlated with both the WMS-IV Delayed Memory Index and Visual Memory Index, 2) GrayMatters Composite score will be significantly, negatively correlated with MMSE score, 3) GrayMatters Composite score will be significantly, positively correlated with (a) Trailmaking A and B completion times and (b) Trailmaking A and B error rates, and 4) GrayMatters Composite scores will be significantly, negatively correlated with Boston Verbal Fluency Test score. Negative correlations were expected on Hypotheses 1, 2, and 4 due to higher scores indicating impairment on GrayMatters Composite and lower scores indicating impairment on the WMS-IV Delayed Memory and Visual Memory Indices, MMSE, and Boston Verbal Fluency Test. Positive correlations were expected on Hypothesis 3 due to higher scores indicating impairment on all measures.

CHAPTER IV

RESULTS

The following sections detail the results of the analyses exploring the concurrent validity of GrayMatters when compared to well-established dementia screening instruments. Preliminary screens were conducted for missing data, and tests that do not have scores from all participants are noted. Finally, exploratory analyses on the influence of gender, race, age, and educational attainment are presented.

Description of Sample

The sample consisted of 40.6% male and 59.4% female participants. Participants had an average age of 76.6 (*SD*=8.1), and the majority (42.6%) of participants fell between the ages of 70 to 79. The sample was 90% Caucasian, and the majority of participants (34.3%) had a high school education. In order to account for any demographic variables, preliminary analyses were conducted. Further information regarding participant variables is presented in Table 1.

Table 1

Participant Demographics

Variable	Percent	*N*
Gender		
Female	59.4	149
Male	40.6	102
Ethnicity		
Caucasian	90.0	226
African-American	2.0	5
Hispanic	7.6	19
Pacific-Islander	0.4	1
Education		
Less than High School	17.5	44
High School	34.3	86
Some College	27.1	68
Bachelor Degree or greater	21.1	53
Age		
Under 60	3.2	8
60-69	15.5	39
70-79	42.6	107
80-89	34.7	87
90+	4.0	10

Note. *N*=251

Concurrent Validity

A total of 251 participants completed the GrayMatters procedures, WMS-IV, Trailmaking parts A and B, Boston Verbal Fluency Test, and MMSE. Although there were a total of 251 participants, only 21 participants completed the Visual-Working Memory portions of the WMS-IV due to age-cutoffs. Correlations between GrayMatters subtest scores and WMS-IV indices scores, Trailmaking parts A and B time to completion and errors, Boston Verbal Fluency Test scores, and MMSE scores were examined.

GrayMatters Scores and Wechsler Memory Scale-IV Indices

Hypothesis 1 predicted that the GrayMatters composite score would be significantly, negatively correlated with both the WMS-IV Delayed Memory Index and Visual Memory Index. Low scores on the WMS-IV predict pathology while high scores on GrayMatters predict pathology; thus the negative relationship was predicted. A Pearson *r* correlation comparing GrayMatters composite score with WMS-IV Delayed Memory and WMS-IV Visual Memory supported this hypothesis. GrayMatters composite score was weakly correlated with WMS-IV Delayed Memory Index, $r(249) = -.21$, $p<.001$, and moderately correlated with WMS-IV Visual Memory Index, $r(249) = -.372$, $p<.000$. Additional analyses revealed a weak correlation between GrayMatters composite score and WMS-IV Auditory Memory Index, $r(249) = -.255$, $p<.000$, a moderate correlation between GrayMatters composite score and WMS-IV Immediate Memory Index, $r(249) = -.414$, $p<.000$, and a strong correlation between GrayMatters composite score and WMS-IV Visual-Working Memory Index, $r(19) = -.618$. $p<.003$. The correlations can be found in Table 2, and the findings suggest that GrayMatters composite score is consistent with WMS-IV indices scores.

Table 2

Correlations between GrayMatters Composite Score and WMS-IV Indices Scores

	GrayMatters Composite Score
Auditory Memory	-.255**
Visual Memory	-.372**
Visual-Working Memory	-.618*
Immediate Memory	-.414**
Delayed Memory	-.210**

*p<.005, **p<.001

Additional analyses exploring GrayMatters scores and WMS-IV Index scores reveal further correlations. A weak, significant, positive (the expected direction) correlation was discovered between GrayMatters Memory score and WMS-IV Visual Memory Index, $r(249) = .241$, $p<.000$. Additionally, GrayMatters Memory score was weakly correlated with WMS-IV Immediate Memory Index, $r(249) = .198$, $p<.002$, weakly correlated with WMS-IV Delayed Memory Index, $r(249) = 132$, $p<.036$, and moderately correlated with WMS-IV Visual-Working Memory Index, $r(19) = .439$, $p<.046$. These correlations can be found in Table 3 and suggest that GrayMatters Memory scores are consistent with Wechsler Memory Scale Index scores.

Pearson *r* correlations exploring the relationship between GrayMatters Executive Function scores and WMS-IV Index scores reveal additional significant correlations. GrayMatters Executive Function scores were weakly, positively (the expected direction) correlated with WMS-IV Visual Memory Index scores, $r(249) = .173$, $p<.006$, and weakly, positively (the expected direction) correlated with WMS-IV Immediate Memory Index scores, $r(249) = .171$, $p<.006$. The correlations can be found in Table 3, and results suggest that GrayMatters Executive Function scores are consistent with WMS-IV Visual Memory and Immediate Memory Index scores.

Analyses exploring GrayMatters Mental Control scores and WMS-IV Index scores suggest further significant correlations. A weak, positive (the expected direction) correlation exists between GrayMatters Mental Control scores and WMS-IV Auditory Memory scores, $r(249) = .226$, $p<.000$, WMS-IV Visual Memory scores, $r(249) = .221$, $p<.000$, and WMS-IV Delayed Memory scores, $r(249) = .124$, $p<.049$. In addition, a moderate, positive (the expected direction) correlation exists between GrayMatters

Mental Control scores and WMS-IV Immediate Memory scores, $r(249) = .345$, $p<.000$. All correlations can be found in Table 3, and findings reveal that GrayMatters Mental Control scores are consistent with WMS-IV Index scores.

Lastly, Pearson *r* correlations exploring the relationship between GrayMatters Overall score and WMS-IV Index scores reveal additional significant correlations. Positive (the expected direction), weak correlations exist between GrayMatters Overall scores and WMS-IV Auditory Memory, $r(249) = .220$, $p<.000$, and WMS-IV Delayed Memory, $r(249) = .172$, $p<.006$. Moderate correlations exist between GrayMatters Overall scores and WMS-IV Visual Memory scores, $r(249) = .310$, $p<.000$, and WMS-IV Immediate Memory scores, $r(249) = .351$, $p<.000$. A strong correlation exists between GrayMatters Overall scores and WMS-IV Visual-Working Memory scores, $r(19) = .652$, $p<.001$. Correlations can be found in Table 3 and suggest that GrayMatters Overall scores are consistent with WMS-IV Index scores.

Table 3

Correlations between GrayMatters Index Scores and WMS-IV Index Scores

	GM Composite	GM Memory	GM Executive Function	GM Mental Control	GM Overall
1. Auditory Memory	-.255**	.113	.102	.226**	.220**
2. Visual Memory	-.372**	.241**	.173*	.221**	.310**
3. Visual-Working Memory	-.618*	.439	.400	.305	.652**
4. Immediate Memory	-.414**	.198*	.171*	.345**	.351**
5. Delayed Memory	-.210**	.132	.088	.124	.172*

*p < .01, **p < .001

GrayMatters Scores and MMSE Scores

Hypothesis 2 predicted that GrayMatters Composite score would be significantly, negatively correlated with MMSE scores. A negative correlation was predicted due to higher GrayMatters Composite scores predicting pathology, while lower MMSE scores predict pathology. A Pearson *r* correlation comparing GrayMatters Composite scores with MMSE scores supported this hypothesis, which means that GrayMatters Composite scores are consistent with MMSE scores. GrayMatters Composite score was moderately correlated with MMSE scores, $r(249) = -.488$, $p<.000$. Additional analyses were conducted comparing the remaining GrayMatters Indices scores and MMSE scores. Weak, positive (the expected direction) correlations were found between MMSE scores and GrayMatters Memory scores, $r(249) = .263$, $p<.000$, and GrayMatters Executive Function scores, $r(249) = .194$, $p<.002$. Moderate, positive (the expected direction) correlations were found between MMSE scores and GrayMatters Mental Control scores, $r(249) = .419$, $p<.000$, and GrayMatters Overall scores $r(249) = .432$, $p<.000$. These correlations can be seen in Table 4, and findings reveal that GrayMatters Indices scores are consistent with MMSE scores.

Table 4

Correlations between GrayMatters Indices Scores and MMSE Score

	MMSE Score
GM Composite	-.488**
GM Memory	.263**
GM Mental Control	.419**
GM Executive Function	.194*
GM Overall	.432**

*p<.005, **p<.001

GrayMatters Scores and Trailmaking A and B Scores

Hypothesis 3 predicted that GrayMatters Composite score would be significantly, positively correlated with a) Trailmaking A and B completion times and b) Trailmaking A and B errors. A positive correlation was predicted due to pathology being predicted by higher scores by both GrayMatters Composite and Trailmaking parts A and B completion time and errors. A Pearson *r* correlation comparing GrayMatters Composite score with Trailmaking part A completion time and Trailmaking part B completion time support part a) of hypothesis 3. GrayMatters Composite score was moderately, positively correlated with Trailmaking part A completion time, $r(246) = .474$, $p<.000$, and moderately, positively correlated with Trailmaking part B completion time, $r(222) = .316$, $p<.000$. Findings suggest that GrayMatters Composite scores is consistent with both Trailmaking part A and B completion times. Correlations between GrayMatters Composite score and Trailmaking completion times can be seen in Table 5.

Additional analyses comparing the remaining GrayMatters Index scores with Trailmaking part A completion times reveal further significant correlations. Weak, negative (the expected direction) correlations exist between Trailmaking part A completion time and GrayMatters Memory scores, $r(246) = -.224$, $p<.000$, and GrayMatters Executive Function scores, $r(246) = -.213$, $p<.001$. Moderate, negative (the expected direction) correlations exist between Trailmaking part A completion time and GrayMatters Mental Control scores, $r(246) = -.371$, $p<.000$, and GrayMatters Overall scores, $r(246) = -.407$, $p<.000$. These results reveal that GrayMatters Index scores are consistent with Trailmaking part A completion times. Table 5 depicts these correlations.

Additional Pearson *r* correlations comparing the remaining GrayMatters Index scores with Trailmaking part B completion times reveal further significant correlations. A weak, negative (the expected direction) correlation was found between Trailmaking part B completion time and GrayMatters Executive Function scores, $r(222) = -.162$, $p<.015$. Moderate, negative (the expected direction) correlations exist between Trailmaking part B completion times and GrayMatters Mental Control scores, $r(222) = -.440$, $p<.000$, and GrayMatters Overall scores, $r(222) = -.303$, $p<.000$. Findings reveal that GrayMatters Index scores are consistent with Trailmaking part B completion times, with the exception of GrayMatters Memory scores. All correlations can be viewed in Table 5.

Separate analyses comparing GrayMatters Composite score with Trailmaking part A errors and Trailmaking part B errors support part b) of hypothesis 3. GrayMatters Composite score was weakly, positively (the expected direction) correlated with Trailmaking part A errors, $r(246) = .295$, $p<.000$, and weakly, positively (the expected direction) correlated with Trailmaking part B errors, $r(222) = .176$, $p<.008$. These findings suggest that GrayMatters Composite score is consistent with both Trailmaking parts A and B error rates. The above correlations can be seen in Table 5.

Additional Pearson *r* correlations comparing the remaining GrayMatters Index scores and Trailmaking part A errors reveal further significant correlations. Weak, negative (the expected direction) correlations exist between Trailmaking part A errors and GrayMatters Memory scores, $r(246) = -.179$, $p<.005$, GrayMatters Mental Control scores, $r(246) = -.193$, $p<.002$, and GrayMatters Overall scores, $r(246) = -.241$, $p<.000$. Results reveal that all GrayMatters Indices, with the exception of GrayMatters Executive

Function, are consistent with Trailmaking part A errors. Correlations can be viewed in Table 5.

Analyses comparing the remaining GrayMatters Index scores and Trailmaking part B errors reveal additional significant correlations. Weak, negative (the expected direction) correlations exist between Trailmaking part B error rates and GrayMatters Executive Function scores, $r(222) = -.199$, $p<.003$, GrayMatters Mental Control scores, $r(222) = -.243$, $p<.000$, and GrayMatters Overall scores, $r(222) = -.245$, $p<.000$. Findings suggest that all GrayMatters Indices, with the exception of GrayMatters Memory, are consistent with Trailmaking part B errors. Correlations comparing all GrayMatters Indices and Trailmaking parts A and B completion times and errors can be found in Table 5.

Table 5

Correlations between GrayMatters Index Scores and Trailmaking Scores

	GM Composite	GM Memory	GM Executive Function	GM Mental Control	GM Overall
1. Trailmaking A Time	.474**	-.224**	-.213**	-.371**	-.407**
2. Trailmaking B Time	.316**	-.009	-.162*	-.440**	-.303**
3. Trailmaking A Errors	.295**	-.179*	-.116	-.193*	-.241**
4. Trailmaking B Errors	.176*	-.002	-.199*	-.243**	-.245**

*p < .01, **p < .001

GrayMatters Scores and Boston Verbal Fluency Test Scores

Hypothesis 4 predicted that GrayMatters Composite scores would be significantly, negatively correlated with Boston Verbal Fluency Test score. A negative correlation was expected due to higher GrayMatters Composite scores predicting

pathology, while lower Boston Verbal Fluency Test scores predict pathology. A Pearson *r* correlation comparing GrayMatters Composite scores and Boston Verbal Fluency Test scores supported this hypothesis. GrayMatters Composite score was moderately, negatively correlated with Boston Verbal Fluency Test score, $r(249) = -.443$, $p<.000$. This finding suggests that GrayMatters Composite scores is consistent with Boston Verbal Fluency Test score. Additional analyses comparing the remaining GrayMatters Indices and Boston Verbal Fluency Test scores were conducted and revealed further significant correlations. Weak, positive (the expected direction) correlations exist between Boston Verbal Fluency Test scores and GrayMatters Memory scores, $r(249) = .215$, $p<.001$, and GrayMatters Executive Function scores, $r(249) = .206$, $p<.001$. Moderate, positive (the expected direction) correlations exist between Boston Verbal Fluency Test scores and GrayMatters Mental Control scores, $r(249) = .420$, $p<.001$, and GrayMatters Overall scores, $r(249) = .419$, $p<.001$. Correlations can be viewed in Table 6, and results reveal that all GrayMatters Indices are consistent with Boston Verbal Fluency Test scores.

Table 6

Correlations between GrayMatters Indices Scores and Boston Verbal Test Score

	Boston Verbal Test Score
GM Composite	-.443**
GM Memory	.215**
GM Executive Function	.206**
GM Mental Control	.420**
GM Overall	.419**

*p<.005, **p<.001

Sample Characteristics

A total of 251 participants who had previously been diagnosed with Alzheimer's disease by a neuropsychologist were included in the study. The sample consisted of more female (*n*=149) than male (*n*=102) participants. An independent samples *t*-test was conducted to investigate differences in scores between genders. Gender differences were examined due to research noting greater levels of female Alzheimer's disease cases than male cases (Alzheimer's Association, 2019). In fact, the Alzheimer's Association *2019 Facts and Figures Report* noted that two-thirds of Americans with Alzheimer's disease are women (Alzheimer's Association, 2019). Results indicated a statistically significant difference between male and female participants on the Boston Verbal Fluency Test. A Bonferroni post hoc test was conducted, and results revealed that male participants had significantly higher scores on the Boston Verbal Fluency Test than female participants. No statistically significant differences on other measures were noted.

The majority of the participants were Caucasian (*n*=226), followed by Hispanic (*n*=19), African-American (*n*=5), and Pacific Islander (*n*=1). Mean differences between groups were unable to be compared due to the small sample size of minority ethnic groups. Further exploration with more evenly distributed ethnic samples is needed to examine group differences by race.

The majority of the participants fell between the ages of 70-79, followed by 80-89, 60-69, 90+, and under 60, respectively. Participants were categorized into groups by age due to the diverseness of participant ages, which ranged from age 50 to 96. Grouping participants by age allowed for investigation into group differences based on age. The number of participants in each age group can be seen in Table 1. A one-way analysis of

variance was conducted to investigate differences in scores among the measures described in the measures section and age. ANOVA results indicated statistically significant differences between age groups on the Auditory Memory portion of the WMS-IV, Immediate Memory portion of the WMS-IV, Trailmaking part B completion time, Trailmaking part B errors, Boston Verbal Fluency Test, GrayMatters Overall, and Mini-Mental Status Examination. A Bonferroni post hoc test was conducted to determine which age categories were significantly different. Results revealed that the age category of 80-89 had significantly lower scores than the age groups under 60 and 70-79 on the Auditory Memory portion of the WMS-IV. Another post hoc test indicated that the age categories of under 60 and 60-69 had significantly lower scores than the 80-89 age group on the Immediate Memory portion of the WMS-IV. In addition, the 60-69 age group had significantly lower scores than the 70-79 age group. A separate Bonferroni post hoc test was conducted, and results reveal that the age categories of 60-69 and 70-79 took significantly longer to complete Trailmaking part B compared to the age group of 80-89. Additionally, a post hoc test indicated that the age categories of 60-69 and 70-79 had significantly higher rates of errors on Trailmaking part B when compared to the age category 80-89. A different Bonferroni post hoc test was conducted and revealed that the age categories of 60-69 and 70-79 had significantly higher scores on the Boston Verbal Fluency Test in comparison to the 80-89 age group. In addition, the age groups of 60-69 and 70-79 had significantly higher scores than the 80-89 age group on the Overall portion of GrayMatters. Lastly, the 70-79 age group had significantly higher scores than the 80-89 and 90+ age groups on the Mini-Mental Status Examination.

Participants were grouped by education into four categories: less than high school (less than 12 years, *n*=44), high school graduate (12 years, *n*=86), some college (13-15 years, *n*=68), and bachelor's degree or higher (16+, *n*=53). A one-way analysis of variance was conducted to investigate differences in scores in measures previously described in the measures section and education level. ANOVA results reveal statistically significant differences among educational attainment categories on Trailmaking part A completion time, Trailmaking part B completion time, Trailmaking part B errors, and the Mini-Mental Status Examination. A Bonferroni post hoc test was conducted to determine which educational categories were significantly different. Results revealed that the education category less than high school education took significantly longer to complete the Trailmaking part A task than the education groups high school graduate and bachelor's degree or higher. Additionally, the less than high school education group took significantly longer to complete the Trailmaking part B task than the high school graduate group. Results further indicated that the less than high school education group made significantly more errors than the high school graduate and some college education groups. Lastly, results reveal that the less than high school education group had significantly lower MMSE scores than the high school graduate, some college, and bachelor's degree or higher groups.

CHAPTER V

DISCUSSION

Purpose and Findings

The purpose of the study was to evaluate the concurrent validity of GrayMatters and replicate the findings regarding validity from the pilot study (Brinkman et al., 2012). GrayMatters was compared to the WMS-IV, Trailmaking parts A and B, Boston Verbal Fluency Test, and the Mini-Mental Status Examination in order to establish concurrent validity in the present study. Previous studies supported the validity of GrayMatters (Brinkman et al., 2012), but the system needed to be validated alongside of the updated WMS and population changes over time. Additional analyses exploring gender, race, age, and education level differences among Alzheimer's disease patients were also explored. The results of this study are first discussed in relation to study hypothesis; followed by study implications, study limitations, and directions for future research.

GrayMatters Scores and Wechsler Memory Scale-IV Indices Scores

The Wechsler Memory Scale-IV is a widely used assessment of dementia that has significant research data to support its' use in diagnosing Alzheimer's disease. It is frequently used to make decisions regarding patient care including diagnosis, medication recommendations, and treatment effectiveness. The present study found that GrayMatters Composite score is consistent with all WMS-IV Indices scores (Hypothesis 1). Additionally, GrayMatters Memory score was consistent with all WMS-IV Indices scores, with the exception of the Auditory Memory index. GrayMatters Executive

Function scores are consistent with WMS-IV Immediate Memory and Visual Memory scores. The Mental Control portion of GrayMatters is consistent with all WMS-IV Indices scores, except for the Visual-Working Memory portion of the WMS-IV. Lastly, GrayMatters Overall scores were found to be consistent with all WMS-IV Indices scores. In other words, all GrayMatters scores are compatible with scores from the WMS-IV; however, GrayMatters Composite and Overall scores seem to be most comparable with WMS-IV Indices scores. These scores are likely most comparable with WMS-IV Indices scores as they incorporate data from all portions of the GrayMatters assessment. That is, both GrayMatters Composite and GrayMatters Overall integrate information regarding the participant's performance on tasks involving memory, executive function, and mental control, so these scores accurately reflect the participant's general mental functioning. The compatibility of WMS-IV Indices scores and GrayMatters scores demonstrates GrayMatters ability to measure cognitive impairment and guide decisions regarding additional patient care.

GrayMatters Scores and MMSE Scores

The Mini-Mental Status Examination is currently the most widely used dementia screening instrument that both medical and psychological practitioners use as a quick measure of changes in cognition and level of decline, as well as determine who should be referred for more extensive evaluation. The present study found that GrayMatters Composite score is consistent with MMSE scores (Hypothesis 2). Additional analyses indicated that all GrayMatters scores (Composite, Memory, Executive Function, Mental Control, Overall) correspond with MMSE scores. The Composite, Mental Control, and Overall portions of GrayMatters had the highest rates of correspondence with MMSE

scores. That is, the scores from these portions of GrayMatters are most indicative of similar scores on the MMSE. The comparability of GrayMatters scores to MMSE scores demonstrates that GrayMatters could be used as a prompt dementia screening assessment to measure cognitive decline and make recommendations regarding patient care.

GrayMatters Scores and Trailmaking A and B Scores

The present study supported the hypothesis that a) GrayMatters Composite score is consistent with Trailmaking parts A and B completion times, and b) GrayMatters Composite scores is consistent with Trailmaking parts A and B error rates (Hypothesis 3). All GrayMatters scores (Composite, Memory, Executive Function, Mental Control, Overall) correspond with Trailmaking part A completion times. Additionally, all GrayMatters scores, with the exception of Memory scores, are compatible with Trailmaking part B completion times. Surprisingly, GrayMatters Executive Function had the weakest correlation with Trailmaking part B completion times, which has previously been shown to be a good measure of executive functioning (Brinkman et al., 2012).

GrayMatters Composite, Memory, Mental Control, and Overall scores were found to be consistent with Trailmaking part A error rates. All GrayMatters scores, with the exception of Memory scores, were compatible with Trailmaking part B error rates. Again surprisingly, of the scores that correlated with Trailmaking part B error rates, GrayMatters Executive Function had the lowest correlation rate. One possible explanation for the lower correlation rate could be that while GrayMatters Executive Function measures strictly aspects of executive functioning, such as rule acquisition and sequencing, GrayMatters Composite and Overall scores include all aspects of brain functioning, including executive function, mental control, and memory.

GrayMatters Scores and Boston Verbal Fluency Test Scores

Finally, the present study supported the hypothesis that GrayMatters Composite score is compatible with Boston Verbal Fluency Test scores (Hypothesis 4). In fact, all GrayMatters scores are consistent with Boston Verbal Fluency Test scores. Interestingly, GrayMatters Mental Control had one of the higher correlations with Boston Verbal Fluency Test scores, which supports the idea that both measure an individual's ability to retrieve information while under a time restriction. GrayMatters Composite, Mental Control, and Overall scores were most highly correlated with Boston Verbal Fluency Test scores. In other words, the scores from these portions of GrayMatters are most indicative of similar scores on the Boston Verbal Fluency Test.

Sample Characteristics

Differences in scores among participants of varying genders, races, education level and ages were examined. Differences regarding sample characteristics are as follows: (1) Gender differences: On Boston Verbal Fluency Test male participants were able to name significantly more animals in one minute than female participants. This gender difference could be due to more female than male participants, which may have lowered the average female score. Females made up approximately 60% of the entire sample. (2) Race differences: Differences in scores among racial groups were unable to be explored due to the small sample size of minority ethnic groups. Future exploration is needed to examine potential racial differences in scores. (3) Education level differences: On the MMSE participants who had less than a high school education had significantly worse scores than participants who had a high school or greater education. This finding is unsurprising as the MMSE requires the participant to employ skills, such as following

multi-step commands, which are practiced frequently in both high school and college courses. On Trailmaking A and B, participants with less than a high school education took significantly longer to complete the task and made more errors than participants with a high school education or greater. These findings are unsurprising as Trailmaking requires the participant to engage in counting, alphabetizing, and rule-shifting skills that are practiced in both high school and college courses. (4) Age differences: Participants in the 80-89 age group had significantly more impaired scores on the WMS-IV Auditory Memory, GrayMatters Overall, MMSE, and Boston Verbal Fluency Test when compared to younger age groups. These findings were not surprising as deficits involving memory, free recall, executive function, and mental control are expected to worsen with age in AD patients. Surprisingly, younger age groups had significantly more impaired scores than older age groups on the WMS-IV Immediate Memory, Additionally, younger age groups took longer to complete and made more errors on Trailmaking part B than older age groups. These unexpected age differences may be due to the smaller sample size of younger age groups.

Limitations

The results of the study should be interpreted with consideration to the unique characteristics of the sample. First, the similarity of the sample demographics limits the ability to generalize to the wider population. The vast majority of the participants were Caucasian, and all data was gathered from a single neuropsychology clinic, causing generalizations to other ethnic groups and geographic areas to be difficult. Another limitation of the study is the inability to validate GrayMatters in other languages. Although the GrayMatters system is available in Spanish, and data was gathered

regarding Spanish-speaking patients, there was a lack of WMS-IV data for Spanish-speaking individuals. The established validity of GrayMatters can only be applied to the English version and should not be generalized to the Spanish version.

Future Directions

Evidence suggests that dementia screening by PCPs is preferable (Fillit et al., 2008; Zygouris & Tsolaki, 2014), and while the GrayMatters system is in place in PCPs' offices, no data has been gathered from these systems. It would be helpful to gather data from the systems in PCPs' offices to confirm GrayMatter's validity in other settings. Gathering data from these offices would also help determine how often PCPs choose to screen their patients and if they have criteria in place for which patients they screen.

It would also be advantageous to research patients' attitudes towards dementia assessment in PCPs' offices versus a neuropsychology clinic in order to explore any differences in patient preference for setting. Assessing patient attitudes would also allow for research regarding attitudes impact on test scores. For example, do patients who are anxious score worse than patients who are not anxious?

Data should be gathered from patients who have other forms of dementia in order to determine GrayMatters validity with regard to dementia in general. Patients with vascular dementia, Lewy-Body dementia, and unspecified dementias should be included in a future study to determine the full extent of the validity of GrayMatters.

Future studies should also examine the education levels of the various age groups. Considering the level of education within the age groups could help to account for variability in scores. Additionally, the possibility of an interaction effect could be examined.

Finally, GrayMatters' predictive validity should be explored. Data should be gathered from both AD patients and non-AD patients who have taken the GrayMatters assessment in order to determine GrayMatters' ability to predict AD diagnosis. This information would help both PCPs and neuropsychologists determine which individuals should be sent for a more thorough neuropsychological examination.

Conclusion

The current study provides support for the validity of the GrayMatters system as a screener for Alzheimer's disease. Specifically, the present study supported the hypotheses that GrayMatters Composite score is compatible with scores from the WMS-IV, Trailmaking parts A and B, Boston Verbal Fluency Test, and the MMSE. Additionally, scores from GrayMatters Memory, Executive Function, Mental Control, and Overall were also found to be consistent with various portions of the WMS-IV, Trailmaking parts A and B, Boston Verbal Fluency Test, and the MMSE. Overall, the current study demonstrates the concurrent validity of GrayMatters.

PCPs should be encouraged to include GrayMatters as part of their general wellness check-up for elderly patients. Including GrayMatters would allow PCPs to be aware of possible cognitive decline or memory deficits that patients may feel uncomfortable discussing or are unaware of. Neuropsychologists should also be encouraged to administer GrayMatters as a screening instrument prior to a full diagnostic evaluation. GrayMatters is a quick, affordable screening measure, and administering it first would allow neuropsychologists to save time, energy, and money. It would also allow patients to save time, energy, and money, as full neuropsychological evaluations are both time-consuming and costly. Neuropsychological assessment may cost upwards

of $1,000, an unfeasible amount for individuals on a fixed income and individuals with a low socioeconomic status. The high cost of evaluation, which is a cause of great concern for many patients, should not be demanded until a valid screening instrument indicates a need for further assessment. Additionally, patients who lack insurance may not seek care due to the high cost of evaluation and would benefit from a low-cost screening instrument. GrayMatters can be used to benefit typically underserved populations due to its' conservative cost, short administration time, and production of immediate results.

Unlike traditional screening measures, GrayMatters is self-administered, so it requires little time out of the busy schedules of both practitioners and patients. Additionally, GrayMatters includes an interpretative report that can be used by professionals and also given to patients. The report is written clearly and offers suggestions specifically for the patient who was evaluated. Furthermore, the report is generated immediately so patients do not need to anxiously await results. Finally, using GrayMatters as a dementia screening tool would allow for early detection of memory loss allowing patients to receive optimal care. The need for early diagnosis and intervention has been established, and the immediacy of results allows the practitioner and patient to make decisions regarding patient care in a timely manner.

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