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The Relationship Between Hallucinations and Visuospatial Impairment Among Individuals with Dementia

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We, the undersigned committee, having examined the submitted doctoral research project, “The Relationship Between Hallucinations and Visuospatial Impairment Among Individuals with Dementia” by Ruta Sohoni, M.S. hereby indicates its unanimous approval.

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Abstract

Title: The Relationship Between Hallucinations and Visuospatial Impairment Among Individuals with Dementia

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Objective: This study examines the neuropsychological functioning, specifically using the Hooper Visual Organization Test (VOT), to understand the impact of hallucinations on the level of impairment in the visuospatial domain.

Method: Archival data obtained over three years from a total of 73 patients from the Health First Memory Disorder Clinic was used in this study. Participants were included in the study if they endorsed experiencing hallucinations, were given the VOT during their brief neuropsychological evaluation, and were diagnosed with dementia or unspecified neurocognitive disorder. The patient's electronic medical record was used to retrospectively gather additional details regarding their hallucinations and fall history to serve as data points.

Results: Results showed no significant difference between the presence of hallucinations and visuospatial impairment. Additionally, there was no significant correlation between visuospatial skills, age, or global cognitive functioning. However, there was a statistically significant, moderately positive correlation between the VOT and Clock Drawing test, though not the BVMT-R copy trial. Lastly, there was no significant difference between poor visuospatial skills and an increased risk of falls.

Conclusion: The overall results of this study suggest that a history of hallucinations does not seem to impact whether the visuospatial domain, as measured by the VOT, is impaired. Additionally, advancing age, more severe global cognitive impairment, and a history of falls do not appear to be related to more significant visuospatial impairment.

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Chapter 1: Introduction

Dementia is a progressive neurodegenerative disease that impairs cognitive domains, such as learning and memory, executive functioning, visuospatial abilities, language, attention, processing speed, mood, and overall personality, as it advances to the later stages (World, 2021). Dementia is the seventh leading cause of death and one of the leading causes of disability (Nichols & Reinig, 2021). As of 2020, it is estimated that roughly 55 million people live with dementia worldwide; this number is expected to double every 20 years due to the fast growth in the elderly population (Mayeux & Stern, 2012).

Alzheimer's disease (AD) is the most common form of dementia diagnosed in the elderly (Mayeux & Stern, 2012). In comparison, dementia with Lewy Bodies (DLB) is often considered to be the second most commonly diagnosed, accounting for roughly 30.5% of all dementia cases at autopsy (Chiu et al., 2017). However, medical providers continue to underdiagnose DLB due to a lack of awareness of diagnostic features and the various clinical presentations of this subtype of dementia (Moylett et al., 2019). Delusions and hallucinations are some of the most common noncognitive psychiatric symptoms seen in patients with dementia (Bassiony & Lyketsos, 2003), particularly in patients with AD and DLB, and become more prevalent as the disease progresses (Wilson et al., 2000). These additional symptoms negatively affect a patient's well-being, furthering their disability and increasing caregiver stress. Patients with dementia also have a higher

comorbidity rate for depression and anxiety (Moylett et al., 2019), furthering their functional impairments caused by dementia. The present study examines neuropsychological testing results among individuals diagnosed with dementia who also reported experiencing hallucinations to determine whether specific patterns of cognitive performance or deficits exist within certain domains, particularly concerning visuospatial skills. Information gathered from this study will help shed light on potential cognitive factors related to the experience of hallucinations in this population. The results may also have implications for treatment planning and recommendations, particularly involving symptom management and maximizing safety related to visuospatial impairment.

Chapter 2: Review of Literature

Visuospatial Skills

Visuospatial skills are necessary for daily functioning, as they govern our ability to understand space in two and three dimensions (Harada et al., 2013). These abilities are typically separated into visual construction skills, which involve the ability to put together individual parts to make a complete whole, and visuospatial abilities, which involve object perception - the ability to recognize familiar objects like faces or household objects - and spatial perception - the ability to understand the physical location of an object either alone or to other objects (Harada et al., 2013). Additionally, visuomotor ability refers to visual information and motor movements working together to coordinate and execute the appropriate movements (Palsetia et al., 2018). Neuroanatomically, two visual pathways play a primary role in visuospatial abilities: the ventral occipitotemporal pathway, where visual information is relayed from the occipital region, located in the lower back region of the head, to the temporal lobes, located above both ears, which is responsible for detailed analysis and identification of an object; and the dorsal occipitoparietal pathway, where visual information from the occipital region transfers up to the parietal region, located at the posterior crown of the head, which is integral to spatial vision and motion perception (Mosimann et al., 2004).

Various neuropsychological tests measure constructional and spatial abilities within the broader visuospatial domain by incorporating tasks requiring a

motor component, such as drawing to reproduce a geometric figure or simply differentiating between visual stimuli and providing a verbal response. For example, the Brief Visual Memory Test-Revised (BVMT-R) measures visual memory and learning (Tam & Schmitter-Edgecombe, 2013) but also includes an optional copy trial involving drawing, which can be administered as an additional measure of visuoperceptual and visuoconstructional abilities (Benedict & Psychological Assessment Resources Inc., 1997). Difficulties such as a skewed depiction of one stimulus figure or incorrectly spacing out the reproductions on a page are common among individuals with impaired visuospatial skills (Tam & Schmitter-Edgecombe, 2013). The Rey –Osterrieth Complex Figure Test (ROCF) and the Visual Reproduction subtest of the Wechsler Memory Scale (WMS) are other prevalent measures of visual memory that incorporate a copying task (Rey & Osterrieth, 1941; Wechsler, 1945). Patients are asked to draw a copy of an abstract visual image, then recall and recreate it from memory after a short delay, followed by another recall trial after an additional 30 minutes. The copy trials involve visuospatial orientation skills, visuomotor abilities, and effective planning and organizing skills to reproduce the abstract image (Zhang et al., 2021).

Similarly, the Clock Drawing Test (CDT) measures visuomotor, visuospatial, and visuoconstructional abilities (Royall et al., 1998). The task instructs patients to recreate a clock face with the appropriate numbers and clock hand placements to read a specific time. Typically, this is done spontaneously without a model for comparison. Accurately representing a clock face and translating the mental image onto paper requires both visuospatial and visuomotor

abilities to be intact. Correct spacing out of the numbers to encompass all sections of the clock face and having the numbers rotated appropriately, rather than inverted or placed "counter-clockwise." are all examples of visuospatial and visuoconstructional abilities are represented in this measure (Palsetia et al., 2018).

Visuoconstructional ability can also be measured without a drawing component, such as the Wechsler Adult Intelligence Scale-4th edition (WAIS-IV) Block Design subtest (Wechsler, 2008), which measures visuocontruction ability by having the patient reconstruct a two-dimensional image using three dimensional, 6-sided blocks within a specific time limit (Mervis et al., 1999). Points are taken off if the constructed blocks are rotated or improperly oriented.

Meanwhile, visual discrimination, or the ability to notice subtle differences between objects or pictures, is measured by tasks such as Judgement of Line Orientation (JLO) (Benton et al., 1975) and the Benton Visual Form Discrimination Test (VFDT) (Benton, 2011). These tests are purely visual and do not integrate a motor or construction component (Campo & Morales-Ortiz, 2003; Spencer et al., 2013). Instead, patients are asked to discriminate between various choices and choose the option that matches the original stimulus by responding verbally.

These various measures are applicable in clinical practice to understand what visuospatial impairments may exist in an aging person, to notice a cognitive

decline, increased falls, or has become a greater risk for accidents while driving on the road (Harada et al., 2013).

Visuospatial Skills and Aging

As previously mentioned, visuospatial abilities regularly allow us to safely navigate the environment by accurately judging of the direction and distance of objects, locating targets in space, perceiving objects, and understanding two and three-dimensional objects (de Bruin et al., 2016). In the normal aging process, perception of objects and spatial perception remains relatively intact, though visuoconstruction skills may somewhat decline (Harada et al., 2013). Neuroanatomical changes, such as declines in gray and white matter volume and white matter function, are also common with the normal aging process. However, it is important to note that these changes do not lead to substantial impairment of functioning in an individual (Harada et al., 2013). Changes that lead to interruption or impairment of daily functioning may indicate further concerns related to aging.

Consequently, visuospatial skills are not impervious to more significant impairments related to neurological or general medical conditions or neurodegenerative diseases. For example, visuospatial neglect is the reduction or loss of spatial abilities often following a stroke and is common among 40% of right-sided and 20% of left-sided strokes occurring within the middle cerebral artery. In contrast, homonymous hemianopia occurs more commonly after a posterior cerebral artery stroke (Zebhauser et al., 2019). Other medical conditions that can impact visuospatial skills, such as diabetic retinopathy, cataracts,

glaucoma, and macular degeneration, are also common in the elderly. These diseases typically affect a person's visual perception, clarity, and central or peripheral vision, clarity, and central or peripheral vision, occasionally resulting in partial or complete blindness. As a result, a decrease in a patient's ability to correctly perceive their environment may increase the risk of falls or other safety hazards. However, as these conditions are not related to a neurodegenerative process, they can occasionally be effectively managed via other methods, such as medication, eyeglasses such as bifocals, compensatory strategies such as more thoroughly visually scanning the immediate environment before moving around, or surgical/ophthalmological procedures (Klein & Klein, 2013).

Additionally, some psychiatric disorders, such as Schizophrenia, show consistent deficits in visual processing and perception (Butler et al., 2008). Patients with Schizophrenia also exhibit hallucinations, often of a voice or figure, or experience delusions, such as thoughts of paranoia or grandeur. Finally, many neurodegenerative diseases cause impairments in aspects of visuospatial skills as well (Iachini et al., 2009).

Alzheimer's Disease (AD)

One of the most common neurodegenerative diseases was discovered in 1910 when Alois Alzheimer coined the term "Alzheimer's Disease" (AD) after a case study of a 50-year-old woman revealed a "peculiar severe disease process of the cerebral cortex" ("The discovery of Alzheimer's disease," 2003). AD is often characterized as a neurodegenerative disorder that initially involves impairments in the ability to form short-term memories, word-finding problems, and language difficulties and gradually progresses to global cognitive impairment (Becker et al., 1994), affecting all domains of cognitive functioning (Mayeux & Stern, 2012). AD

accounts for approximately 70% of all dementia cases in the elderly aged 65 and older (Moya-Alvarado et al., 2016). Visuospatial drawing and copy abilities are often impaired in the beginning stages of AD, along with language functions, including semantic fluency, comprehension, and confrontational naming (Karantzoulis & Galvin, 2011).

Multiple theories have been proposed regarding the pathology of this disease, such as an altered metabolism of the amyloid precursor protein (APP), creating amyloid plaques within the cortex; an altered process in the formation of the tau protein which creates neurofibrillary tangles; neurotransmitter and hormone imbalances (i.e., acetylcholine, serotonin, norepinephrine, glutamate); or hippocampal sclerosis (López & DeKosky, 2008). Specifically, cortical atrophy in AD is seen to impact medial temporal (ventral stream) and posterior temporoparietal (dorsal stream) regions within the cortex (Rabinovici et al., 2008). Although the primary visual cortex seems to be spared in many cases of AD, particularly earlier in the course of the disease, the areas responsible for the association of objects to visual cues become impaired (Possin, 2010), which likely contributes to some of the visuospatial deficits observed among individuals with AD.

To streamline the diagnostic criteria for AD, the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) was created by the National Institute on Aging (NIA) in 1986 (Morris et al., 1989). CERAD was used to standardize further, validate, and compile the appropriate neuropsychological and

neuropathological measures to make an AD diagnosis (Fillenbaum et al., 2008). In addition, CERAD created norms for various neuropsychological tests among clinic patients, community residents, and various ethnic and racial groups in various languages to be internationally used (Fillenbaum et al., 2008). Meanwhile, the Diagnostic and Statistical Manual for Mental Disorders (DSM-V) has established criteria for major and minor neurocognitive disorders (NCD), with major NCD typically encompassing neurodegenerative diseases such as AD. DSM-V diagnostic criteria for major NCD require the presence of memory deficits and impairments in at least one other cognitive domain (i.e., language, attention, executive functioning), in combination with difficulties performing activities of daily living (ADL) and adaptive functioning.

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one other cognitive domain (i.e., language, attention, executive functioning), in combination with difficulties performing activities of daily living (ADL) and adaptive functioning. In addition to cognitive symptoms, patients with AD can exhibit many common psychological symptoms, such as depression and anxiety, increased aggression, delusions, and visual and auditory hallucinations (Bassiony & Lyketsos, 2003; López & DeKosky, 2008). *Hallucinations* are defined as seeing or hearing something in the absence of an external stimulus. Hallucinations are occasionally noted in a patient with dementia when the caregiver observes the patient respond to or interact with a nonexistent person or object (Holroyd et al., 2000). Hallucinations are linked with older age and seem equally present in males and females (Bassiony & Lyketsos, 2003). Visual and auditory hallucinations occur in roughly 23% of patients with AD and are associated with more significant cognitive impairment and rapid deterioration (El Haj et al., 2017). Visual and auditory hallucinations are the most common forms; however, somatic, olfactory, and tactile hallucinations have also been reported (El Haj et al., 2017).

Interestingly, visual hallucinations in AD have been significantly associated with the neuropathology of the visual cortex; specifically, volume loss of the occipital lobe compared to the whole brain volume and hypoperfusion of the parietal lobes bilaterally (Holroyd et al., 2000). A study found hallucinations correlated with reduced thickness in the lateral parietal cortex (Blanc et al., 2014). Conversely, another study found occipital lobe atrophy in patients who experienced hallucinations (Reeves et al., 2012). Hypoperfusion, hypometabolism, and atrophy within the bilateral dorsolateral frontal left ventral striatal, left anterior cingulate,

left pulvinar, and dorsolateral parietal cortex regions have also been observed in individuals with AD who experience hallucinations (El Haj et al., 2017). Together, these studies suggest that atrophy of the parietal lobes and parts of the occipital and frontal lobes is most consistently implicated in the presence of hallucinations among individuals with AD.

In addition to this neuroanatomical basis for hallucinations, there also appears to be a genetic component. A relationship between hallucinations in AD and the apolipoprotein E (ApoE) ε4 allele has been observed, suggesting that individuals with this allele are more likely to experience hallucinations (Waters, 2003). Notably, this allele exists on chromosome 19 and plays a role in the spontaneous presentation of AD that may occur (Waters, 2003).

Other cognitive theories illustrating a relationship between inhibitory dysfunction and hallucinations in AD suggest that difficulty in suppressing intrusive thoughts and memories from resurfacing might contribute to the presence of hallucinations (El Haj et al., 2017). Patients with AD often exhibit diminished emotional responsiveness, hyperactivity, irritability, and disinhibition (Lin et al., 2018). Meanwhile, increased feelings of loneliness, social isolation, and depression are related to an increased presence of hallucinations in AD (El Haj et al., 2017). More specifically, it has been hypothesized that AD patients who are isolated and lonely lack external stimulation and social contact to fulfill their need to communicate and, therefore, hallucinate to escape the cycle of boredom and feelings of emptiness (Llorca et al., 2016). While medications or therapeutic

strategies can occasionally manage mood and behavioral symptoms, the cognitive decline will continue as the disease progresses.

Dementia with Lewy Bodies (DLB)

Fatefully in 1912, at the same lab as Alois Alzheimer, Fritz Heinrich Lewy described neuronal, intracytoplasmic spherical inclusions in the brain of patients with diagnosed Parkinson's disease. This finding would later become known as "Lewy bodies" (Rodrigues e Silva et al., 2010). DLB is typically recognized as the second or third most common neurodegenerative dementia after AD (Cagnin et al., 2012; Chiu et al., 2017; Moylett et al., 2019; Yamamoto et al., 2006; Hamilton et al., 2012), depending on diagnostic criteria, typically accounts for approximately 20-25% of all dementia cases (Hamilton et al., 2012; Cagnin et al., 2012), and incidence estimates are between 2.4 to 5.9% in the global population (Kane et al., 2018). Primary symptoms include fluctuating cognition, visual hallucinations, and physical parkinsonism features related to Lewy bodies within the brain (Harding et al., 2002). Patients with DLB can also exhibit apathy and executive dysfunction (Lin et al., 2018).

While DLB and Parkinson's Disease (PD) are similar in their neuropathology, as Lewy bodies are present in both diseases, the distinction is made based on the duration of parkinsonian symptoms prior to the onset of dementia (Mosimann et al., 2006). Specifically, a PD diagnosis requires parkinsonism for at least one year prior to experiencing cognitive decline, whereas, in DLB, cognitive decline is usually observed first or simultaneously with parkinsonism (Walker et

al., 2019). Parkinsonism symptoms include movement abnormalities, such as slowness, tremors, impaired speech production, or muscle stiffness (Jellinger & Korczyn, 2018). Even after a dopaminergic pharmacological intervention, visual hallucinations are more likely to occur among individuals with PD (Jellinger & Korczyn, 2018). Meanwhile, one of the initial core features of DLB does include visual hallucinations, which may be present in up to about 70% of all DLB patients (Rosenblum et al., 2021), compared to about 14% in patients with AD (Chiu et al., 2017), and about 75% with PD (Weil & Reeves, 2020). Visual hallucinations are typically well-formed and complex, occurring in approximately 68-73% of patients with DLB. These hallucinations are usually of people, animals, or objects and typically do not include things such as hallucinations of flashes, dots, or otherwise commonly seen in an eye disease (Mosimann et al., 2006; Van Assche et al., 2018).

The underlying mechanism of visual hallucinations among patients with DLB is still relatively unknown; however, hallucinations have been observed along with visuospatial, visuoconstructional, visuoperceptual, or attention impairments (Hamilton et al., 2012; Mosimann et al., 2004). Patients with DLB also show executive functioning deficits and, at times, show behavioral disturbances resulting from frontal lobe dysfunction (Peavy et al., 2013). However, impaired activity in the lateral frontal cortex and the ventral visual stream is associated with visual hallucinations in patients with DLB (Collerton et al., 2005). Findings such as this suggest that impairments in these areas may play a role in developing visual hallucinations (Rosenblum et al., 2021). In a study that examined potential visuospatial deficits and neuropsychological performance in later autopsied

patients, severe visuospatial deficits were found in patients with DLB and were related to the presence of visual hallucinations (Hamilton et al., 2012).

Furthermore, among patients with autopsy-confirmed DLB, visual hallucinations were significantly more prevalent among patients who exhibited severe visuospatial dysfunction despite otherwise exhibiting relatively mild global cognitive deficits than those who did not exhibit severe visuospatial dysfunction (Hamilton et al., 2012). Additionally, neuropsychological testing of visuospatial functioning appeared to help identify patients with suspected Lewy body disease who developed the prototypical features of DLB, including visual hallucinations (Hamilton et al., 2012). Additionally, greater awareness of these symptoms contributes to creating more effective treatment plans, improving caregiver education, and furthering the current research regarding visual hallucinations and visuospatial deficits.

Utilization of the Hooper Visual Organization Test (VOT) to Assess Visuospatial Skills

The VOT is a 30-item neuropsychological test that measures deficits within the visuospatial domain. Each test item consists of various line drawings of everyday objects, which are fragmented and reorganized such that the patient will have to mentally manipulate each fragment to correctly identify the object without a time limit (Hooper, 1983). The VOT requires the mental manipulation and integration of spatial information and object identity processed by the brain's dorsal and ventral neural streams (Paxton et al., 2007). The VOT has also been sensitive

to and specific for identifying visuospatial dysfunction, with patients with DLB performing worse than patients with AD (Mitolo et al., 2016).

fMRI correlations during the VOT administration show cortical activation in the dorsal occipitoparietal pathway, suggesting visuospatial processing is needed to perform visual integration, while activation of the ventral occipitotemporal pathway indicates the area optimized for object identification (Moritz et al., 2004). Additionally, activation of the temporal neocortex indicates that these additional structures are needed for object naming and semantic retrieval. This reveals a language component to the VOT, although it is primarily a test that loads onto the visuospatial domain. Indeed, the VOT may tap into visuospatial and language skills among patients with AD, as this task also contains a confrontational naming component (Paxton et al., 2007). In situations where a patient scores poorly on the VOT, it would be beneficial to assess scores of other tests in the visual-spatial domain, which may involve copying or drawing figures to confirm the presence of visuospatial deficits, as well as scores on expressive language measures, to understand whether the poor VOT score is genuinely reflective of poor visuospatial skills (Paxton et al., 2007). If poor language scores exist while other visuospatial tests appear normal, it might imply an interference of language dysfunction in the VOT score (Paxton et al., 2007).

Other studies have attempted to clarify the relationship between neuropsychological testing performance and hallucinations. For example, Cagnin et al. (2012) examined 81 patients with DLB from an outpatient memory clinic in

Italy, 41 of whom experienced visual hallucinations, to investigate which clinical and neuropsychological characteristics are associated with visual hallucinations in patients with DLB compared to patients diagnosed with AD. The evaluation of whether patients with AD experienced any hallucinations or not is unclear. Age, level of education, and gender were comparable across AD and DLB groups. This study revealed that the MMSE score showed no significant difference between patients with DLB and AD, although patients with DLB showed more significant impairment of attention and visual constructional abilities and performed worse than the AD group (Cagnin et al., 2012). Overall, patients with DLB showed impaired processing of visual information, visual-perceptual, and visual-spatial abilities (Cagnin et al., 2012). This can be expressed as impaired perceptive identification of images and the altered spatial localization of visual stimuli (Cagnin et al., 2012). These specific visuospatial deficits were also related to the presence of visual hallucinations; however, it was not indicative of a cause for the hallucinations (Cagnin et al., 2012). For example, AD patients with equally poor visuoperceptual deficits, compared to patients with DLB, do not necessarily develop visual hallucinations or readily act as an indicator of dementia severity (Hamilton et al., 2012).

Additionally, patients diagnosed with DLB who experienced visual hallucinations obtained lower MMSE scores and lower attention and executive functioning scores (Cagnin et al., 2012). Altogether, this study found that impaired visual attention, as a predisposing cognitive feature, is related to the experience of

hallucinations in DLB. Additionally, visuoperception deficits, advanced age, and later onset of DLB were associated with visual hallucinations.

Furthermore, Rosenblum et al. (2021) explored the possibility of using standard brief cognitive screeners rather than more in-depth and lengthy neuropsychological tests to measure visuospatial dysfunction in a clinical setting. This study examined 69 patients who met diagnostic criteria for probable DLB; 45 reported having visual hallucinations. Patients had comparable ages, levels of education, times of diagnosis, and MoCA scores (Rosenblum et al., 2021) and were evaluated by an experienced neurologist who determined whether they were experiencing complex-formed visual hallucinations or not. The overall aim of the study was to examine whether global cognitive functioning measures (the MMSE and MoCA) were able to adequately alert clinicians to the presence of visual hallucinations in patients with DLB rather than a more in-depth neuropsychological test such as the VOT by comparing copying, drawing and visual organization abilities in patients with and without visual hallucinations (Rosenblum et al., 2021). Interestingly, patients with DLB who endorsed visual hallucinations scored lower on the MMSE, which briefly assesses global cognitive functioning in the elderly, than those who did not endorse visual hallucinations (Rosenblum et al., 2021). Results also suggested that patients with hallucinations demonstrated impaired drawing and visual organization ability, and misrepresentation of numbers and time are common in patients with DLB; however, copying ability remained intact (Rosenblum et al., 2021). Overall, this study supports the notion that information

obtained from the VOT helps to understand visuospatial dysfunction in an individual experiencing visual hallucinations.

Current research has shown how the VOT can assess visuospatial skills when a patient with DLB is experiencing hallucinations and then use other visuospatial tasks to understand whether other aspects of visuospatial skills are impaired (Rosenblum et al., 2021). The VOT has also been used to measure visuospatial impairment in an AD population, and it was discovered that visuospatial impairments existed without hallucinations (Hamilton et al., 2012). In comparison, current literature seems to lack a connection between VOT performance and the presence of hallucinations regardless of the dementia subtype. With increasing age and increased risk of falls in dementia patients, poor visual-spatial abilities would likely impair their ability to coordinate movements in their environment. Exploring and comparing the VOT to other measures of visuospatial skills, similar to a previous study (Cagnin et al., 2012), will help illustrate how the VOT may help measure visuospatial skills toward tailoring recommendations to ensure patient safety.

Chapter 3: Study Purpose

This study aims to examine the neuropsychological functioning, specifically using the Hooper Visual Organization Test (VOT), in a memory disorder population to understand the impact of hallucinations on the level of impairment in the visuospatial domain. The VOT is this study's preferred objective measure of impaired visuospatial skills over a self-report measure. As patients progress in their dementia diagnosis, they often lack insight regarding their symptoms. Often a family member or caregiver is contacted to obtain collateral information. To ensure level of insight is not affecting the outcome of this study, an objective measure was chosen to measure current visuospatial skills.

Fully understanding the impact of hallucinations on the visuospatial domain can help family members and caregivers of a patient understand how to better care for their loved ones who are experiencing cognitive difficulties. Additionally, creating a better understanding of the risk of falls and the impairment of the visuospatial domain will alert caregivers and medical providers to be more aware of these potential deficits and what could be done to keep the patient safe once they begin to show symptoms of cognitive decline.

Chapter 4: Objectives and Hypotheses

Objective #1: To determine whether patients with dementia who experience hallucinations have greater visuospatial impairment than patients with dementia who do not experience hallucinations.

Hypothesis #1: Patients with hallucinations diagnosed with dementia will have significantly worse VOT scores compared to patients with dementia who do not endorse hallucinations, indicating greater impairment in visuospatial skills.

Objective #2: To explore the relationship between visuospatial skills and age among patients diagnosed with dementia who experience hallucinations.

Hypothesis #2: Patients with dementia who experience hallucinations will have a negative correlation between scores on the VOT and increasing age, suggesting greater declines in visuospatial skills with advanced age.

Objective #3: To explore the relationship between visuospatial skills and global cognitive status among patients with dementia who experience hallucinations.

Hypothesis #3: Patients with dementia who experience hallucinations will demonstrate a positive correlation between VOT scores and MoCA scores, suggesting that poorer visuospatial skills correlate with more severe global cognitive impairment.

Objective #4: To examine the relationship between the VOT and other visuospatial measures (i.e., Clock drawing task, Brief Visual Memory Test- copy trial raw score).

Hypothesis #4: The VOT will show a positive correlation with both other measures of visuospatial skills, indicating performance on the VOT is related to performance on other measures within the visuospatial domain.

Objective #5: To understand whether poor VOT scores are related to fall risk.

Hypothesis #5: Individuals with a history of falls will have poorer VOT scores compared to individuals without a history of falls, indicating an increased risk of falls among individuals with greater impairment in their visuospatial skills.

Chapter 5: Method and Procedures

Data Collection

This study utilized archival and newly collected data between 2018-2022 from the Health First Memory Disorder Clinic in Melbourne, Florida. All participants are administered a brief fixed neuropsychological battery and the VOT. This test was administered when the patient or the patient's primary caregiver endorsed hallucinations or other visual disturbances to the geriatrician and social worker within the EMR. Subsequently, diagnostic impressions are made based on the overall presentation of evaluation data, including information obtained during the initial visit with the provider and social worker, which included the psychosocial history, onset of memory loss or other cognitive problems, medical history, along with the reported IADLs, review of neuropsychological test data, as well as the review of available brain imaging. This study focuses on patients diagnosed with major neurocognitive disorders, including Alzheimer's disease and dementia with Lewy Bodies. Other diagnoses typically given include, but are not limited to, mild cognitive impairment, mixed dementia, Vascular dementia, unspecified dementia, and unspecified neurocognitive disorder.

Participants

A total of 73 patients were tested between 2018 and 2022 who were given the VOT at the time of neuropsychological testing. Sixteen of these patients did not meet the inclusion criteria for this study. These sixteen patients were either diagnosed with normal cognition, mild cognitive impairment, depression, anxiety,

premorbid schizophrenia, or experienced hallucinations as an adverse effect due to medication. After removing individuals who did not meet these criteria, 57 (36 females) patients were included in the current study. These 57 patients were included if they were diagnosed with dementia or unspecified neurocognitive disorder and were given the VOT. Of these 57 patients, 39 (M = 78.54, SD = 7.44) patients endorsed hallucinations (i.e., visual, auditory, etc.) while 18 (M = 78.50, SD = 7.50) patients did not. These patients with and without hallucinations are not significantly different in age $t(55) = -.018$, $p = .986$. The mean age for all 57 patients was 78.53 (SD = 7.40).

Additionally, the majority of these participants self-identified as Caucasian (n =52, 91.2%), while the remaining patients identified as African- American (5.3%) and Native American (3.5%). See *Table 1* for a further demographic breakdown of the participants. Twenty-six patients endorsed falling, while 31 patients had no recorded history of a fall. See *Table 2* for a further breakdown of endorsed hallucinations and recorded fall history.

A statistical power analysis was performed for sample size estimation based on data from the published study of Rosenblum et al. (N=69), comparing 45 patients with visual hallucinations to 15 who did not endorse any. This study's effect size (ES) was .5 and is considered to be medium using Cohen's (1988) criteria. With an alpha = .05 and power = 0.80, the projected sample size needed with this effect size is approximately N = 100 for this between-group comparison.

Inclusion criteria include patients experiencing hallucinations as noted in their medical records (visual, auditory, or otherwise) and suspected cognitive decline. Additionally, those who have completed a brief neuropsychological evaluation with the VOT included in the battery and received a diagnosis of Alzheimer's Disease, dementia with Lewy bodies, Vascular dementia, mixed dementia, unspecified dementia, and unspecified neurocognitive disorder were included. Exclusion criteria were applied to patients who experienced hallucinations due to an adverse effect of medications, were diagnosed with mild cognitive impairment, cognition within normal limits with depression and anxiety, or had a premorbid diagnosis of schizophrenia.

Coding

Detailed information was gathered from the electronic medical record to appropriately categorize a patient's hallucinations and whether they have a documented history of falls. The researcher used the following codes; 1= visual hallucinations, 2= auditory hallucinations, 3= olfactory, somatic, etc. 4 = information missing or unclear but hallucinations are endorsed, 5 = combination of hallucinations were endorsed (i.e., auditory and visual; auditory, visual, and somatic), 0= no hallucinations endorsed. History of falls was coded as such; 1= previous falls exist, 2= no fall history indicated in the history.

Chapter 6: Measures

Cognitive functioning is assessed by measuring various cognitive domains such as; visuospatial abilities, language, learning, memory, executive functioning, attention, processing speed, and adaptive functioning were tested using the following assessments: Supraspan Word List, Brief Visual Memory Test-Revised (BVMT-R), COWAT, Boston Naming Test, Short Form, Western Aphasia Battery (WAB) Comprehension and Repetition, Boston Diagnostic Aphasia Examination (BDAE) Cookie Theft Picture, Trail Making Test A & B, Stroop Color and Word-Golden version, Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV) Digit Span, Modified Wisconsin Card Sorting Test (M-WCST), Clock Drawing Test, Geriatric Depression Scale (GDS), Geriatric Anxiety Inventory (GAI), Texas Functional Living Scale (TFLS), and the Hooper Visual Organization Test (VOT). All tests were attempted; the VOT was administered if deemed appropriate for the patient (i.e., they have visual disturbances or hallucinations). Tests may not have been attempted if there were time constraints, or they may have been discontinued due to patient confusion or frustration.

Hooper Visual Organization Test (VOT)

This test is designed to assess neurological impairment quickly, explicitly testing for visual organization and synthesis skills (Hooper, 1983). The VOT consists of 30-line drawings; each item shows common, everyday objects that have been cut into various pieces and scattered on the page, similar to a puzzle. The patient will then tell the examiner what the object would be if the pieces were put

together. Half-points may be awarded if the patient's answer is consistent with the general concept of what the test item is depicting. Correct responses were awarded one point, and responses correctly identified- but did not name- the object was awarded a half-point. The total VOT raw score is converted into a T-score from age-based norms for interpretation. This test typically takes about 15 minutes to administer in a clinical setting. This instrument shows high reliability (r = 0.80, $p < .001$) and a positive moderate correlation of 0.82 in college-age students between split-halves, and 0.78 in a psychiatric inpatient setting (Gerson, 1974; Hooper, 1948).

Clock Drawing Test

The Clock Drawing Test (Royall et al., 1998) is a brief, 5-minute screener measuring cognitive functioning, typically administered to the elderly population. The patient is asked to fill in clock numbers on a page with a pre-drawn circle. Once the patient has completed this step, they are instructed to draw the hour and minute hand to read a specific time. Inaccuracies are typical for individuals with impaired motor, executive, or visuospatial functioning. Scoring is done on a 10-point system, with a point deducted for more minor errors and two points for a major error. A score of 6 or below is typically seen as below expectation (Royall et al., 1998).

Brief Visuospatial Memory Test- Revised (BVMT-R), Copy Trial

The BVMT-R is a commonly used measure of visuospatial learning and memory abilities (Benedict et al., 1996) in a neurologically impaired population.

The BVMT-R comprises three consecutive learning trials for 10 seconds, where a 2x3 array of figures is presented to the patient, and they must reproduce the figures from memory. After a 25-minute delay, the patient is asked to draw the figures again from memory, then a forced-choice recognition and an optional copy trial are administered. Patients given the optional copy trial must copy the figure array as accurately as possible. Two points are awarded for accuracy and correct placement of each figure, for a possible maximum score of 12. Partial credit may be awarded for inaccurate yet recognizable figures or improperly placed, though accurate, figures. Raw scores are converted to T-scores from age-based norms for interpretation (Benedict, 1997); however, the copy trial score remains a raw score out of 12.

Montreal Cognitive Assessment (MoCA)

The MoCA is a standardized memory screener commonly used to measure global cognitive functioning in clinical settings. Moreover, detect cognitive impairment within the aging population by examining a range of domains, such as visuospatial, executive functioning, language, attention, memory, abstract reasoning, and orientation. Any physician, psychologist, or healthcare professional may administer the MoCA to understand the level of impairment. The total possible raw score obtained is 30, with their education level corrected by adding 1 point for individuals who completed 12 years or less of formal education. A score below 25 is considered to be outside the normal limits. Otherwise, higher scores indicate more intact global cognitive functioning (Nasreddine et al., 2005).

Chapter 7: Procedure

All participants presented to a local memory disorder clinic due to concerns regarding their cognition. They underwent a formal physical examination and clinical interview with the geriatrician and social worker. Additionally, a psychosocial history report of current independent activities of daily living (IADL) is obtained from the patient and a collateral source (i.e., spouse, child, primary caregiver.) The social worker also administers a brief cognitive screener, the Montreal Cognitive Assessment (MoCA), to assess impairment level. The geriatrician will then recommend a neuropsychological evaluation if it is deemed appropriate to gather information for developing a treatment plan. A clinical psychology doctoral student administered testing under the supervision of a board-certified licensed clinical neuropsychologist. All patients signed a consent form that outlined their permission to participate in research; their data would remain de-identified for this purpose. Patients would then undergo approximately a 2-hour neuropsychological battery in English. The battery assessed multiple cognitive domains for functioning: language, executive functioning, visuospatial skills, learning, memory, attention, processing speed, and adaptive functioning.

After an evaluation, a multidisciplinary case review consists of a neurologist, geriatrician, neuropsychologist, pharmacist, social worker, and clinical psychology doctoral students. Once the clinical case and testing data are interpreted, a diagnosis and recommendations are made to aid in the treatment plan for the patient. Exclusionary criteria include any patient diagnosed with cognition within normal limits with or without depression and anxiety, regardless of whether

they are experiencing hallucinations, as it may be possible this is a symptom of a psychiatric disorder.

Chapter 8: Data Analysis

All data was collected from the Health First Memory Disorder Clinic research database. Informed consent is obtained from each participant prior to the neuropsychological evaluation. A t-test will compare VOT scores and fall history to the overall impairment level of the visuospatial domain. Correlation analysis will determine whether the VOT scores depict a relationship between age and overall impairment. Descriptive analyses will be gathered to understand the sample's overall mean, standard deviation, and demographic variables. Data will be analyzed using the Statistical Package for the Social Sciences (SPSS)- Version 27.

Chapter 9: Results

Statistical Analyses

Hallucinations and VOT Scores: A comparison of performance on the VOT was conducted to determine whether patients with dementia who experience hallucinations have greater visuospatial impairment than patients with dementia who do not experience hallucinations. An independent-samples t-test could not be conducted as the sample was not normally distributed. Therefore, a Mann-Whitney U test was conducted to determine whether differences in VOT scores were present between patients with (n = 39) or without (n = 18) hallucinations. Distributions of the engagement scores for males and females were not similar, as assessed by visual inspection. VOT scores (M = 16.75, SD = 4.84) for patients with hallucinations

(mean rank = 33.78) and VOT scores (M = 18.17, SD = 4.30) for patients without hallucinations (mean rank = 26.79) were not statistically significantly different, U = 265, z = -1.478, p = .139. These results do not support the first hypothesis that patients with dementia who experience hallucinations have greater visuospatial impairment than patients who do not have hallucinations.

Visuospatial Skills and Age: A bivariate correlational analysis was conducted to assess the relationship between age (M = 78.5, SD = 7.40) and VOT score among individuals with dementia who experience hallucinations. There was no statistically significant correlation between age and VOT score, $r(39) = -.019$, $p = .908$, with age explaining only .04% of the variation in VOT scores, suggesting increasing age is not negatively correlated to visuospatial skills. This does not support the second hypothesis that advanced age is not related to greater impairment in visuospatial skills.

Visuospatial skills and Global Functioning: A bivariate correlational analysis was run to assess the relationship between global cognitive status (M = 16.75, SD = 4.84), as measured by the MOCA, and visuospatial skills among individuals with dementia who experience hallucinations. There was no statistically significant correlation between MOCA and VOT scores, $r(39) = .149$, $p = .386$, suggesting poorer visuospatial skills are not correlated with more severe global cognitive impairment. This does not support the third hypothesis that patients with hallucinations have impaired visuospatial skills and global cognitive impairment.

VOT and other visuospatial domain measurements: A bivariate correlational analysis was conducted to assess the relationship between another task

measuring visuospatial skills (i.e., Clock Drawing) and the VOT score in the entire population of patients with and without hallucinations. There was a statistically significant, moderate positive correlation between the scores of the Clock drawing task and VOT scores $r(55) = .400$, $p < .01$, with test scores explaining 16% of the variation in VOT scores. Similarly, a bivariate correlational analysis was conducted to assess the relationship between a different task measuring visuospatial skills (i.e., BVMT- copy trial) and VOT scores. There was no statistically significant correlation between the score of the BVMT-R copy trial and VOT scores, $r(55) = .-.084$, $p = .536$.

Visuospatial Skills and Fall Risk: To determine whether poor VOT scores in patients with and without hallucination are related to an increased fall risk, an independent-samples t-test could not be conducted as the sample was not normally distributed. Therefore, a Mann-Whitney U test was conducted to determine if there were differences in VOT scores between those with and without a fall history. Distributions of the engagement scores for males and females were not similar, as assessed by visual inspection. VOT scores for patients who have fallen previously (mean rank = 28.58) and patients who have not fallen (mean rank = 29.50) were not statistically significantly different, $U = 390$, $z = -.209$, $p = .835$.

Chapter 10: Discussion

Impact of Study

Developing a better understanding of whether the experience of hallucinations impacts visuospatial skills and fall risk of individuals with

dementia would aid family members, caregivers, and medical providers in better assisting the patient, especially as their dementia progresses. This study aimed to understand the relationship between patients who have hallucinations and their level of visuospatial impairment, as measured by the VOT, and the potential increase in fall risk. This study also looked at a potential relationship between age, global cognitive functioning, and visuospatial skills. Lastly, the relationship between VOT scores and other measures in the visuospatial domain (i.e., Clock drawing and BVMT-R copy trial) were examined to understand if the performance on the VOT was related to other measures.

Hypothesis 1: The presence of hallucinations was not significantly related to poorer VOT scores, failing to support the first hypothesis. Although the analysis was not significant, visual inspection of the mean raw scores of the VOT for patients with and without hallucinations suggested a possible trend toward those without hallucinations performing better than those with hallucinations, making it conceivable that this analysis may have been statistically significant if the sample size was larger which remains consistent with the sample size suggested by the power analysis. Furthermore, the heterogeneity of the sample used was likely a contributing factor. Specifically, individuals were included in the study if they were administered the VOT, reported any prior hallucinations, and were subsequently diagnosed with dementia (i.e., Alzheimer's disease, vascular dementia, mixed dementia, dementia with Lewy bodies, frontotemporal dementia, unspecified dementia) or unspecified neurocognitive disorder. The decision was made not to require greater specificity regarding the type of neurodegenerative disease

diagnosis to maintain an adequate sample size. However, using a diagnostically heterogeneous sample likely results in various characteristics of distinct neurodegenerative diseases being represented. This likely contributes to more significant variability in symptom presentations and cognitive profiles. For example, patients with Alzheimer's disease will often have difficulty with confrontational naming on neuropsychological testing, which impacts how they verbally respond to certain stimuli (Karantzoulis & Galvin, 2011).

Additionally, a diagnosis of unspecified dementia often indicates extraneous or complicating factors in a patient's history that precluded diagnostic specificities, such as a history of substantial brain injury or current excessive alcohol use. However, suppose a homogenous sample of patients diagnosed with a specific type of dementia, such as dementia with Lewy bodies, which notably includes hallucinations in the diagnostic criteria, were included. In that case, it may allow for different, likely significant results as the sample explicitly targets a particular symptom consistent with the diagnostic criteria. Thus, making it more straightforward when concluding and achieving the expected results. Furthermore, since information regarding hallucinations was obtained retrospectively, more detailed information regarding the precise frequency and nature of hallucinations and their possible etiology was not always clear. While individuals with a documented experience of hallucinations resulting from medication side effects were excluded, it is possible that alternative etiologies of hallucinations were not consistently documented in the patient's medical records. This may have resulted in some individuals with hallucinations related to other factors, such as medication

side effects being inadvertently included in this study. Future studies would benefit from collecting more specific data regarding the nature of hallucinations preemptively so that patients who appear to be having hallucinations due to alternative reasons (i.e., medications, pre-existing conditions) can be more accurately excluded.

It is of note that in an elderly population, the experience of hallucinations is also possible due to other medical conditions, such as a urinary tract infection (UTI) that has been left untreated. An untreated UTI is known to cause delirium and leads to an acute onset of symptoms such as mental status changes, sudden behavioral changes, and at times episodes of psychosis where auditory or visual hallucinations may occur (Lee et al., 2019). While patients included in this study were not believed to be actively delirious during the interview and assessment process, it cannot be ruled out with certainty that they were not in a delirious state when the hallucination(s) occurred. This point is important to note as it may account for patients who have only experienced a hallucination at one point in time due to another medical condition rather than experiencing hallucinations on an ongoing basis, which would be more typical among individuals who are experiencing hallucinations related to a neurodegenerative disease process specifically. Though this detailed information could not be obtained for all participants in this study, it remains possible that some participants included may not have experienced a hallucination as a symptom related to neurodegenerative disease. Additionally, out of the 57 participants involved in this study, 24.6% of participants (n = 24) were

also diagnosed with unspecified depression, while 19.3% (n = 11) were diagnosed with unspecified depression and unspecified anxiety.

Severe depression has been linked to episodes of psychosis, particularly in the elderly population (Tampi et al., 2019), meaning that hallucinations and delusional thinking are common symptoms that may manifest. It is unclear if the hallucinations experienced by these patients are attributable to their diagnosis of depression. Future studies should attempt to exclude patients diagnosed with a psychiatric condition (i.e., depression, schizophrenia) to allow for a homogenous sample. This could be achieved by conducting a clinical interview prior to inclusion in the study to assess for any pre-morbid diagnoses.

Hypothesis 2: There was no relationship suggested between VOT scores and age. The population presenting to the Memory Disorder Clinic is skewed compared to the average population, with most patients above 65. In this sample, the youngest patient was 63 while the eldest was 93, and the average age of patients was 78. About 81% (n = 46) of the sample used fell between the ages of 70 and 89. This sample is smaller than what would be ideal for this study, partly due to fewer patients with hallucinations presenting to the clinic. Since age and VOT scores were not correlated, this suggests there may not be an increased risk between older age and visuospatial impairment, even though advanced age is the most significant risk for developing dementia (Mayeux & Stern, 2012). Meaning, for a population of individuals with dementia, being older does not appear to be related to having a more severe visual-spatial impairment

Hypothesis 3: Similarly, there was no relationship between VOT scores and global cognitive functioning. While previous research has suggested that a relationship should exist, the results of this study indicate that individuals with more significant global cognitive impairment do not appear to have a greater visual-spatial impairment. This suggests that individuals with dementia may have substantial impairments in other areas of cognition before visual-spatial skills are impacted. For example, patients with AD (n = 15) have been seen to first show impairments in learning, memory, and executive functioning before all cognitive domains eventually become impacted in later stages (Mayeux & Stern, 2012; Becker et al., 1994). The results in this study may be indicative of this pattern. Although some patients may exhibit substantial cognitive impairment in other domains, visuospatial skills may initially be relatively preserved, as assessed in this study by the VOT.

Hypothesis 4: VOT scores and the Clock drawing test showed a positive, moderately strong correlation. This supports part of the fourth hypothesis and suggests that both tests measure aspects of the same construct, namely visuospatial abilities. Specifically, lower scores on both tests, which incorporate visual organization skills, suggest they can detect impaired skills. However, the VOT and the BVMT-R copy trial score did not show a correlation. This discrepancy may be due to the VOT and the Clock Drawing task requiring similar cognitive skills to complete the task, while the BVMT-R copy trial does not. The VOT incorporates a mental reconstruction of fragments into a whole object, while the Clock Drawing

test requires patients to space out numbers and clock hands correctly. Therefore, both tasks incorporate visual planning, organizational skills, and require a mental representation of visual information. Meanwhile, the BVMT-R copy trial incorporates a drawing component that focuses on replicating geometric figures while looking directly at those figures – no mental reconstruction is necessary to perform this task correctly, and visuospatial planning is relatively minimal. Therefore, patients experiencing deficits in specific visuospatial skills may perform consistently poorly on visual organization and planning tasks while still performing well on visual reproduction and replication tasks.

It would be beneficial to explore whether the other neuropsychological tests measuring other aspects of visuospatial skills, such as the Rey Complex Figure Test (RCFT) or Block Design (BD) from the Wechsler Adult Intelligence Scale, 4th Edition (WAIS-IV), show utility in understanding the relationship between patients with dementia with hallucinations and visuospatial skills. The RCFT and BD are standard neuropsychological tests incorporating visuomotor and executive functioning skills such as visual organization, orientation, and planning skills. Similarly, the VOT involves visual organization, orientation, and synthesis skills to identify objects. Understanding whether the VOT shares a relationship with other tests that measure these same skills would allow for understanding how well the VOT can tap into these particular skills. For example, while the BVMT-R copy trial measures some of the same skills and incorporates a visuomotor component similar to the RCFT, as they both require replicating and drawing shapes and geometric

figures, the RCFT has a lot more detail and involves substantially greater planning and organization in comparison to the stimuli on the BVMT-R.

Meanwhile, external factors such as essential tremors or patients having to use their non-dominant hand to draw due to other neurological injuries such as stroke can negatively impact patients' ability to draw figures correctly independent of their visuospatial skills, per se. Therefore, other tests that rely less heavily on manual dexterity might be preferred. BD applies a similar principle to the VOT in that cut-up portions of an image are rearranged using blocks rather than relying on a mental representation only as the VOT requires. Still, BD eliminates the vital fine motor component required in drawing and replication and instead asks the patient to manipulate fragments to create a whole object, somewhat similar to the VOT. Therefore, future studies would benefit from uncovering a potential correlation between the BD subtest and VOT to understand if these instruments measure similar visuospatial skills.

Hypothesis 5: Additionally, there was no significant difference between fall history and VOT scores, suggesting poorer VOT scores are not necessarily related to increased fall risk. It is worth noting that increased fall risk in an elderly population may be present concerning many other medical or physical conditions, such as pelvic or lower extremity pain, recent surgeries, or total joint replacements. Additionally, specific cardiac conditions such as fluctuations in blood pressure, vestibular balance disorders that inner ear problems could cause, medication side effects, and other medical factors can also potentially contribute to an increased risk of falls (Agrawal et al., 2013). Symptoms of these conditions may include

lightheadedness, dizziness, or double vision, which could also contribute to a fall. Future research might consider identifying the underlying cause or contributing factors to patients' falls and incorporating these factors into the inclusion/exclusion criteria. Specifically, by documenting individuals who appear to be experiencing falls related to a neurodegenerative process such as Lewy Body disease rather than other physical or medical factors, a more circumscribed population could be obtained to identify a potential relationship between visuospatial skills and fall risk. If this relationship were to be established, patients who show impaired visuospatial skills as their dementia progresses might be able to receive additional support sooner. For example, adaptive equipment in the home for increased safety and mobility, modified physical exercise routines to strengthen muscles, and medical/pharmacological intervention to assess for medications or physical conditions that may increase fall risk.

Chapter 11: Limitations

This study included 57 participants with dementia who were given the VOT during their neuropsychological evaluation. The smaller sample size has likely underpowered the study, preventing statistically significant results from being extrapolated. A future study with a larger, homogenous sample may provide more information and yield significant results. Specifically, a sample incorporating only individuals who have hallucinations and have been diagnosed with DLB, have no current or past psychiatric diagnoses (i.e., depression), and whose previous falls were not a result of mobility or vestibular deficits

Meanwhile, language skills, such as confrontational naming and comprehension, are necessary to perform well on the VOT. In patients with language and comprehension impairments, their VOT score may be lower than expected as they may have more difficulty understanding task instructions and communicating the name of the object they see, even if their visuospatial abilities are otherwise intact. Future research might consider language skills in this regard and attempt to exclude individuals who appear to have language deficits sufficient to interfere with VOT performance.

Finally, this study retrospectively obtained information regarding the patient's background, medical history, and hallucinations from the electronic medical record. This information was initially collected by a geriatrician, geriatric nurse practitioner, or social worker for clinical purposes rather than research purposes. As such, certain information may not have been gathered uniformly. Future studies could obtain more prominent details regarding the nature of patients' hallucinations by creating and following a more specific clinical interview template or checklist. Mainly information regarding the frequency (i.e., how often and at what time(s) during the day), quality (i.e., level of detail visibly, audibly, or tactilely experienced), and content (i.e., what is said, heard, or felt during their experience) of the hallucinations could be obtained in greater detail.

Similarly, having greater detail regarding the frequency of falls a patient has experienced would be helpful. As noted above, patients in this study were included

if they had experienced at least one fall or if there was a mention of a fall history in their medical records. However, a concrete number of falls and how often they occur would provide additional information to explore the relationships between fall history and any potential visuospatial deficits.

Chapter 12: Conclusion

Despite several limitations, the overall results of this study suggest that a history of hallucinations does not impact whether the visuospatial domain, as measured by the VOT, is impaired. Additionally, advancing age and more severe global cognitive impairment do not appear to be related to more significant visuospatial impairment. Similarly, a history of falls does not appear to be related to increased visuospatial impairment either. However, regarding the objective measure used, the VOT does appear to discern skills related to visual organization and planning; however, it does not seem to reflect visual reproduction (drawing) or visuomotor skills.

Significant limitations appeared to impact this study and potentially confound expected results, including; a restricted sample size comprised of a diagnostically heterogeneous population, potentially confounding pre-existing diagnoses (i.e., psychiatric conditions) that might have contributed to symptoms reported, and the process of obtaining a patient's information and case history retrospectively, which limited availability of some data points of interest. Future studies would benefit from collecting data proactively, streamlining the process to obtain information, and acquiring a more focused sample group by concentrating on one specific diagnosis, like DLB only. Future studies may also explore how

different neuropsychological tests, which measure specific skills in the visuospatial domain, may indicate whether the presence of hallucinations impacts the visuospatial domain.

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Chapter 14: Appendices

Table 1. *Descriptive Statistics of Patient Demographic Information*

Variable		N	Percent
Participants given the VOT			
Gender			
	Female	36	63.2
	Male	21	36.8
Race and Ethnicity			
	Native American	2	3.5
	African American	3	5.3
	White	52	91.2
	No Response	53	93.0
	Hispanic	4	7.0
Age			
	60-69	9	15.8
	70-79	23	40.4
	80-89	23	40.4
	90+	2	3.5
Diagnosis			
	Alzheimer's Disease	15	26.3
	Vascular Dementia	1	1.8
	Dementia with Lewy Bodies	2	3.5
	Frontotemporal Dementia	1	1.8
	Unspecified Dementia	15	26.3
	*Mixed Dementia	15	26.3
	Parkinson's Disease Dementia	1	1.8
	Unspecified Neurocognitive Disorder	7	12.3
Mental Health Diagnosis			
	Depression	14	24.6
	Anxiety	3	5.3
	Depression and Anxiety	11	19.3

*refer to table 3 for further breakdown

Table 2. *Descriptive Statistics of Hallucinations and Fall History*

Variable	N	%
No Hallucinations	18	31.6
Hallucinations		
Visual Hallucinations	26	45.6
Auditory Hallucinations	1	1.8
Information Missing/Unclear	9	15.8
Combination of Hallucinations	3	5.3
Fall History		
Patients with Falls	26	45.6
Patients with No Falls	31	54.4

Table 3. *Descriptive Statistics of Mixed Dementia*

Variable	N	%
Mixed Dementia		
Alzheimer's Disease and Dementia with Lewy Bodies	3	5.4
Alzheimer's Disease and Vascular Dementia	8	14.4
Alzheimer's Disease and Alcohol Induced	2	3.6
Alzheimer's Disease, Vascular Dementia, and Dementia with Lewy Bodies	2	3.6