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Construct Validity for the Poreh Nonverbal Memory Test on Participants with Right, Left, and Bilateral Temporal Lobe Epilepsy

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CONSTRUCT VALIDITY FOR THE POREH NONVERBAL MEMORY TEST ON

PARTICIPANTS WITH RIGHT, LEFT, AND BILATERAL TEMPORAL LOBE

EPILEPSY

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ABSTRACT

The present study examined the construct validity of a novel nonverbal memory measure,

the Poreh Nonverbal Memory Test (PNMT), using a heterogeneous sample of patients

with epilepsy. Results from this study shows that the PNMT differentially correlated with

existing memory measures. Namely, the PNMT delay scores significantly correlated with

ROCF delay scores, and RAVLT delay and ROCF delay scores were significantly

correlated with each other. However, the PNMT did not significantly correlate with

RAVLT, which was hypothesized. PNMT and RAVLT learning trials produced

logarithmic learning curves that indicate both are good measures of learning. When

controlling for gender, education, and ethnicity confounds, results show PNMT delay,

ROCF copy, RAVLT Post-Interference, RAVLT delay, and RAVLT total all

significantly correlate with location of epilepsy (right, left, and bilateral). Unfortunately,

sensitivity and specificity were not able to be analyzed based on the self-report

localization of the patient's seizures. When examining global versus local features of the

ROCF, ROCF Copy Global features significantly correlates with location of epilepsy.

Some limitations include age, gender, education, and ethnicity confounds, lack of access

to medical charts to determine right, left, or bilateral epilepsy, and the small sample size.

Overall, the PNMT provides an alternate method for nonverbal memory assessment and

is able to differentiate between right and left hemispheric damage, similarly to the ROCF.

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INTRODUCTION

1.1 Purpose of Present Study

For decades, neuropsychologists have been using graphomotor tasks, such as the copying of geometric designs, to assess nonverbal memory. Such methods of assessment tend to be confounded by motor deficits and the tendency of subjects to employ verbal strategies when copying the figures. The Poreh Nonverbal Memory Test (PNMT) was created as a "pure" measure of nonverbal learning that is not impacted by the aforementioned confounds. Previous normative data has shown that the PNMT has good construct validity when compared to other well-known memory measures such as the Rey-Osterrieth Complex Figure (ROCF) and Rey Auditory Verbal Learning Test (RAVLT) (Poreh, 2012; Kociuba, 2011; Phelan, 2013; Teaford, 2016). However, studies of the PNMT have not been conducted with patients with localized brain damage.

The present study examines the PNMT with patients who have temporal lobe epilepsy (TLE) in order to help establish the construct validity of the new measure. It was hypothesized that patients with Left Temporal Lobe Epilepsy (LTLE) will perform worse on verbal measures (RAVLT), while Right Temporal Lobe Epilepsy (RTLE) patients will perform worse on nonverbal measures (PNMT and ROCF). Since LTLE and RTLE patients perform differently on verbal versus nonverbal measures (Bonner et al., 2015), it was hypothesized that the PNMT will differentiate between the two types of TLE, thus increasing the sensitivity and specificity on this measure for the diagnosis of this population.

1.2 Cognitive Basis of Memory

Memory is one of the most important constructs of the human mind; without memory, individuals would be unable to recognize faces, be alert for dangers, or remember events. It is the brain's responsibility to process each memory, and decide which ones should be destroyed, placed in short-term memory, or consolidated into long-term memory. Through the years, researchers have discovered the various processes that it takes to store information vital to survival and adaptation (Barmeier, 1996). To first discuss memory, multiple components need to be addressed.

Memory has three processes: encoding, storage, and retrieval. First, encoding involves converting a perceived stimulus into a construct so it can be stored as a memory. Encoding requires an individual to pay attention to the stimuli. In addition, associating new information with other information, called elaboration, strengthens encoding. For

example, when an image is associated with a word, the chance of recalling the word at a later time is increased (Sweeney, 2009).

The second stage of memory is storage. This stage involves retaining the information that was gathered during the encoding stage. The three pathways that memory can be stored into are sensory, short-term, and long-term memory. Sensory memory stores perceptions, like sights and sound, which only lasts a fraction of a second. Short-term memory or working memory lasts for 20 to 30 seconds (Sweeney, 2009). Working memory is used when information is held and manipulated in order to achieve some desired goal. However, for short-term memory to hold the information, rehearsal needs to be performed (Purves et al., 2012). Researchers have found that, on average, only six or seven chunks of information can be held in short-term memory for a short period of time. Chunks refer to a set of information that is grouped together based on similarity. The last pathway to storage is long-term memory. If a person rehearses the information long enough, it will be become stored into long-term memory, where that information will not be forgotten easily. During this process of storing, the brain prohibits any other information from being attended to, while hindering any loss of the data to be stored. Over time, if the information is accessed repeatedly, the brain organizes the information further; thus, making the memory permanent (Barmeier, 1996).

Once the memory is stored in long-term memory, a person should be able to retrieve it when needed. Retrieval can occur unwillingly or willingly. A memory elicited by a familiar smell would be an example of an unwilling retrieval. However, remembering what you ate for breakfast when someone asks would be a willing retrieval of a memory. There are two types of retrieval; recall and recognition. Recall and

recognition are easily explained in an example of taking a test. Recall involves

reproducing information that was previously stored, such as listing the cranial nerves

without any cues. Recognition involves identifying learned items. So, if a list of cranial

nerves and brain structures was given, a student who has learned those topics would be

able to delineate which were cranial nerves and which were brain structures (Sweeney,

2009).

Memory has two major qualitative categories: declarative and nondeclarative.

Memories that involve the conscious thought processes, that is, phone numbers or lyrics

to a song, are called declarative or explicit. Memories that are unconscious, i.e. riding a

bike, are called nondeclarative or implicit (Purves et al., 2012). Retrieval is essential in

the formation of memories. If a memory cannot be accessed for later use, there is no

necessity in storing that memory.

Finally, researchers and clinicians distinguish between verbal and nonverbal

memory. This distinction is not only based on the content of the material to be encoded,

but also our current understanding of the neuroanatomical structures associated with the

ability of primates and humans to encode and remembering of new information.

1.3 Neuroanatomy of Memory

The process of memory depends upon the strength of the connections between

cells (neurons) found in the brain. Action potentials can be described as the electric

current that acts as a signal that leads to a release in neurotransmitters which passes

through a synapse to allow communication between neurons. An action potential is

measured through electrical activity. Two processes that affect the activity and strength

of synapses are long-term potentiation and long-term depression. Long-term potentiation is a long-lasting enhancement of the postsynaptic potential, which increases the chance of the postsynaptic neuron firing. Long-term depression is a long-lasting reduction of the postsynaptic potential between the synapses. Once long-term potentiation occurs between synapses, the communication among synapses becomes more effective (Ashwell, 2012).

Throughout the years, researchers have been performing experiments to access the location of the storage of memories and have discovered that memories are not just stored in one location of the brain. Rather, the learning and recall of new information involves several complex structures, particularly the right and left hippocampi. The hippocampi, are structures found in the temporal lobes, and entorhinal cortex (Ashwell, 2012). The right hippocampus has been shown to encode and retrieve nonverbal information, whereas the left hippocampus is known to store and retrieve verbal information (Burgess, Maguire, & O'Keefe, 2002). Removal of one hippocampus leads to domain specific (verbal/nonverbal) memory impairments. Namely, patients with damage to one hippocampus will use the non-impacted hippocampus to compensate for their deficits. In such cases, only a very detailed assessment using "pure" domain specific measures would be able to detect the damage. When both hippocampi are damaged, a person would be unable to form new memories. For declarative memory, the brain regions that are necessary include the association cortex regions in the prefrontal, parietal, and temporal areas, hippocampus, and cortical regions around the hippocampus. To form long-term declarative memories, sensory information is streamed through the association cortex to the hippocampus, where the information is reinforced with other stored information through long-term potentiation, then the manipulated information is

sent back to the association cerebral cortex where it is stored. Nondeclarative memory, however, is stored differently through a process involving a looped circuit involving the cerebral cortex, striatum, thalamus, and back to the cerebral cortex (Ashwell, 2012).

1.4 Lateralization and Localization of Language

The brain is divided into two different hemispheres that both play central roles in language. The right hemisphere dominates the emotional content of language, while the left hemisphere dominates lexicon, grammar, and syntax of speech. Two areas specific to localization in language is Broca's and Wernicke's area. Broca's area is located in the left frontal lobe and affects production of language. Wernicke's area is located in the left temporal lobe that is responsible for understanding spoken language. Lesions to these areas cause different issues with language. Broca's aphasia causes difficulty in speaking, but comprehension is intact, while Wernicke's aphasia causes poor comprehension, with intact speech production (Bear, Connors, & Paradiso, 2007; Purves et al., 2012).

Much research has been performed on split-brain patients to examine how lateralization effects language. The left hemisphere controls speech, while the right hemisphere controls reading, and the comprehension of numbers and letters. Therefore, each hemisphere has its own functions: right for comprehending language, left for vocalizing language (Bear et al, 2007).

1.5 Temporal Lobe Epilepsy and Nonverbal Memory

Seizures occur when neurons fire in synchrony either through the entire cerebral cortex (generalized seizure) or only in a localized area of the cortex (partial seizure). Epilepsy is diagnosed when a person experiences repeated seizures. To date, there is no known cause of epilepsy, but it is known that other diseases can cause a seizure. Partial seizures, localized in the temporal lobe, can cause damage to the hippocampus and amygdala, thus impairing memory, learning, thought, and language (Bear et al., 2007).

In order to examine TLE structurally, fMRI scans have been the most effective way to do so. Haneef and colleagues examined TLE brains against control brains to see if any significant structural differences existed. Researchers found changes to hippocampal functional connectivity throughout the cerebrum. It was shown there was an increase in connectivity to the temporal lobes, frontal lobes, and cerebellum for TLE. Increased right frontal lobe connectivity was present for TLE patients compared to controls. Abnormal hippocampi showed a decrease in connectivity; the greater the abnormality, the greater the reduction. In order to further comparisons, left and right TLE participants were examined. LTLE participants showed greater connectivity changes compared to RTLE. Specifically, LTLE shows greater connectivity in the hippocampus (Haneef et al., 2014). From these structural changes, functional changes can be examined and compared to explore potential causal factors.

A comprehensive review of TLE and its effect on various cognitive functions was conducted by Zhao and colleagues (2014). Cognitive domains that appear to be affected by TLE include: working memory, autobiographical memory, executive functioning, and language/speech. Working memory (WM) is the foundation of short term memory

(STM) and long term memory (LTM). If WM is impaired, it affects storage of memories in STM and LTM. WM deficits also affect visuospatial and verbal WM abilities. Zhao and colleagues examined possible explanations for impairment of WM and found three factors: number of seizures/age of onset, lateralization, and hippocampal damage. Poorer performance on working memory were found for those with an earlier age of onset and more number of seizures (Zhao et al., 2014).

In regard to language impairments involving TLE, a fMRI study found that TLE patients showed greater activation to non-word stimuli compared to word stimuli (Zhao et al., 2014). In addition, patients who have TLE have been found to perform poorly on word naming abilities. These findings were first discovered by Mayeux, Brandt, Rosen, & Benson who were intending to find effective tests in studying temporal lobe epilepsy. Originally, TLE was examined through verbal memory functions by naming objects. However, since word-finding deficits are present in those with TLE, these measures do not provide an accurate verbal memory assessment (Mayeux, Brandt, Rosen, & Benson, 1980; Raspall et al., 2005). In order to follow-up with Mayeux's work, a literature review was conducted by Bartha-Doering and Trinka in 2014 to examine effect of verbal assessment on TLE. Results found that 17% of participants with TLE exhibited language deficits, with issues arising from hippocampal damage (Bartha-Doering & Trinka, 2014).

1.6 Lateralization in Temporal Lobe Epilepsy

A study conducted by Helmstaedter, Pohl, and Elger examined the effect of verbal versus nonverbal assessments on patients with TLE due to discrepancies between left and right hemispheres. Right temporal lobe patients were hypothesized to rely on

verbalization of a task since these patients have visual learning deficits. However, left temporal patients commonly suffer from verbal memory deficits while visual memory is intact. Results confirmed that RTLE patients retained less information for a visual task compared to LTLE patients (Helmstaedter et al., 1995). Other studies confirm this idea that LTLE patients perform poorly on verbal measures, while RTLE patients perform poorly on nonverbal measures (Bonner et al., 2015). Many other studies have provided evidence to support that those with LTLE are impaired on verbal tasks, while those with RTLE are impaired on visual tasks (Narayanan et al., 2012; Glosser, Cole, Khatri, DellaPietra & Kaplan, 2002). With these findings, it provides further support that verbal memory assessments are ineffective for those with TLE and an effective nonverbal memory assessment needs to be implemented. For lateralization, dependent upon left or right side of seizure can cause certain issues. LTLE made more errors on verbal span tasks, while RTLE made more errors on visuospatial tasks. Lastly, hippocampal damage can cause issues on tasks involving spatial memory tasks (Zhao et al., 2014).

Another study had participants perform a task that gave insight into left versus right TLE on object location memory tasks. Participants were asked to memorize the position and location of objects on a flat surface, after a specified amount of time, the objects were taken away and the participant had to reposition the objects exactly as they were before, while paying attention to specific location and position. Results showed that those with RTLE performed worse on the location of the objects, while LTLE participants performed worse on the position of the objects (Frisch & Helmstaedter, 2014).

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A set of studies was examined to see the effect the MTL plays on memory encoding in association with the hippocampus by using fMRI. Research has shown that reorganization occurs for those with unilateral TLE in order to encode material-specific information. Results support previous research on left TLE patients having greater activation in a damaged, left hippocampus which causes better performance on verbal memory tests, and the opposite for right damaged hippocampi. Further research has found that this reorganization only occurs if there is a lack of tissue in the MTL, and performance does not change regardless if reorganization occurred (Figueiredo et al., 2008; Peng, Wu, Zhang, & Chen, 2015; Powell et al., 2007). Studies were conducted to examine verbal versus nonverbal memory with the MTL. Many verbal memory impairments in left MTL epilepsy patients were associated with a degeneration of the hippocampus (Peng, Wu, Zhang, & Chen, 2014). fMRI studies play a crucial role in determining how atrophy of the hippocampus can affect performance on verbal versus nonverbal tasks, as well as how the brain reorganizes in order to compensate for deficit.

1.7 History of Memory Tests

The first memory tests were developed as a part of intelligence tests to determine the best soldiers to fit higher-ranking positions in the military during World War I. The first memory test was digit-symbol substitution, which is similar to modern memory tests found on the WAIS-IV. Since World War I, memory tests have expanded to include various tasks assessing cognitive domains in nonverbal, verbal, attention span, immediate memory, delayed memory, visuo-spatial, and more (Surprenant, Bireta, & Farley, 2007).

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The most widely known memory scale to date is the Wechsler Memory Scale (WMS) that is used to assess various brain abnormalities. Portions of the tests were published by Yerkes (1921) and were later incorporated by David Wechsler (1945). The most recent scale, the Wechsler Memory Scale – Fourth Edition (WMS-IV; Pearson 2009), contains tests for both verbal and visual memory. WMS-IV also includes a measure of working memory compared to the previous revisions (Kent, 2013). This test has shown to be the best at assessing lateralization memory problems due to the division between auditory and visual memory assessments (Bouman, Elhorst, Hendriks, Kessels, & Aldenkamp, 2016).

Rey Auditory Verbal Learning Test (RAVLT)

The RAVLT is a measure used to assess a person's ability to encode, consolidate, store, and retrieve verbal information. It is a widely-used test that measures verbal learning and memory, but is influenced by various variables including age, education, intelligence, and gender (Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2005). Normative data has been collected on select populations to establish the validity of the measure (Schoenberg et al., 2006; Poreh, Sultan, & Levin, 2012).

Results, particularly presurgical participants with RTLE and LTLE, showed the RAVLT exhibited a hit rate range (the ratio of true positives and true negatives compared to the total number of classifications) of 42.7 to 81.3% for LTLE, and 40.0 to 73.1% for RTLE indicating the RAVLT is moderately good at predicting lateralization of TLE (Schoenberg et al., 2006). Phelan (2013) found RAVLT to be better at detecting verbal learning than nonverbal learning. A study conducted by Loring and colleagues (2008)

found the RAVLT to be a sensitive and specific measure in detecting side of seizure focus on patients who underwent anterior temporal lobectomy. The RAVLT was even found to be a superior test when compared to other well-known verbal measures. These studies show the RAVLT is a good measure for verbal memory, but poor at detecting nonverbal memory.

One of the advantages of RAVLT is that it can measure learning by assessing memory in five trials, commonly referred to as a learning curve, with the slope as a measure of verbal learning. The learning curve allows clinicians and researchers to examine the progress of encoding processes (immediate recall) with each consecutive trial. Tulving discussed this learning curve through intertrial and intratrial retention, with intratrial retention involving only the first trial, and any consecutive trials as intertrial retention. Intratrial retention generally stays the same across trials since it is based off information that is new to the person. Intertrial causes the logarithmic learning curve because with each trial the person will change in performance (Tulving, 1964).

To provide support for Tulving's work, studies have been conducted on a normal and epileptic population. The normal population was tested on all five trials of the free-recall sessions in order to determine whether a logarithmic function existed. It was shown that a logarithmic function existed that was determined primarily from the participant's immediate memory span (Poreh, 2005). For the epileptic population, a logarithmic learning curve was found, with those who had a higher medial temporal lobe (MTL) volume showing more learning (Fernaeus, Julin, Almqvist, & Wahlund, 2013). As such, the RAVLT provides a learning curve for normal and epileptic populations.

Rey-Osterrieth Complex Figure (ROCF)

The Rey-Osterrieth Complex Figure (ROCF) was developed to measure perceptual organization and visuospatial memory. The measure best suits those suffering from brain damage. Studies have shown that the ROCF external variables, such as age and education, confound the results of the measure (Gagnon, Awad, Mertens, & Messier, 2003).

One important clinical tool the ROCF provides is being able to determine global and local information processing deficits, thus determining lateralization of lesions. Right hemisphere damage exhibits deficits in copying the ROCF, while left hemisphere damage exhibits the ability to copy and recall the global features, but deficits in copying local features. In terms of frontal lobe damage, participants show a high score on copy, but impaired recall trials on the ROCF. (Gazzaniga, 2000; Poreh & Shye, 1998). Thus, right hemisphere damage should cause impairment on global portions of the copy trial with impaired recall, while left hemisphere damage should cause impairment on local portions of the copy trial, but recall is intact.

Lastly, compared to the RAVLT which measure verbal memory, ROCF measures visual memory. However, because it consists of only one trial, it is considered to be a measure of retention. Some research has been shown that ROCF and RAVLT do not differ in verbal strategy use, thus implying ROCF may not be entirely a nonverbal measure (Hubley & Jassal, 2006). Since no other valid nonverbal assessment has been developed to combat the ROCF, clinicians still rely on this measure.

1.8 Importance of Nonverbal Memory Tests

Memory assessments utilizing verbal administration and response have been widely used for years as the central approach to determine a person's memory capacity. However, issues arise when relying solely on verbal memory tests. The rate of learning measurement differs dependent upon verbal or nonverbal assessment, with nonverbal assessment being able to discriminate what stage an individual is on (control, MCI, or mild dementia). Nonverbal measures provide valuable information for predicting memory decline associated with mild cognitive impairment (MCI) and Alzheimer's Disease (AD) (Bonner-Jackson, Mahmoud, Miller, & Banks, 2015). Nonverbal measures also allow researchers to isolate certain functions based on the absence of language confounds. A measure of right temporo-limbic functions can be compromised if a verbal test is used (Helmstaedter, Pohl, & Elger, 1995). Since Loring et al. (2008) showed that the RAVLT and BNT, widely used verbal assessments, can be used to detect LTLE, it is important to develop a measure that can identify RTLE.

1.9 Poreh Nonverbal Memory Test

The PNMT is a new measure developed in order to assess nonverbal memory. It was developed by drawing from the Morris Water Maze utilized by rodent researchers. The task involves placing a rodent in a pool filled with cloudy water and measuring the time and location in which it finds the arm placed in the water. After repeated trials, the rodent is expected to take less time and know the location of the arm (Poreh, 2012).

The PNMT embodies the Morris Water Maze by including hidden objects that are to be found, then committed to memory for recall later in the task. Similar to the Morris

Water Maze, the PNMT measures memory by removing spatial cues, while repeatedly

presenting the stimuli. With this task, it is presumed that the repeated presentations cause

learning and creates a memory via the hippocampus. To be considered a pure measure of

visual spatial memory, the PNMT is designed to prevent organizational and planning

skills from being utilized during the task in order to only allow memories to be formed

among the association cortex and hippocampus (Kociuba, 2011). The test is administered

through presenting participants with nine cards containing various patterns of white

boxes. The participant must find the red box for each of these nine patterns presented

over five trials. It is expected that the location of the red box will be committed to

memory, then will be recalled for each of the five trials.

Normative data for the PNMT has been collected through various sources. First,

113 participants in a study conducted by Poreh (2012) found that learning on the PNMT

significantly correlated with learning on the RAVLT. Results also showed that the PNMT

is an accurate predictor of verbal learning and memory, with a significant increase in

learning occurring with each trial. Kociuba (2011) found the PNMT was a good measure

of nonverbal memory and was shown to be an easier task to perform compared to the

ROCF.

Another study on the PNMT examined the performance of abstinent alcoholics.

Phelan (2013) showed nonverbal memory was impaired in abstinent alcoholics and that the

PNMT was not affected by education, where ROCF and RAVLT scores are effected.

Results in this study confirmed previous findings of Poreh and Kociuba (Poreh, 2012;

Kociuba, 2011; Phelan, 2013). The most recent study, Teaford (2016), compared the

PNMT with the Biber Figure Learning Test, which is a commonly used measure of

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nonverbal and visuospatial abilities. The PNMT was found to correlate with the Biber Figure Learning Test through performance and learning curve. From these studies, the validity of the PNMT has been established, but further study examining the test with lateralized memory deficits has been encouraged.

Based off the previous nonverbal memory assessments currently used, no one is particularly close to measuring pure visual memory. Heilbronner (1992) provides five issues when attempting to assess visuospatial memory. First, participants may use verbal cues to help memorize nonsensical objects. The PNMT attempts to prevent this occurrence by providing patterns that cannot be described by a word. Unfortunately, the easier items are more susceptible to this phenomenon.

In addition, issues arise for the time interval between presentation and recall, particularly with right temporal lobe deficits. The present study is meant to establish norms for this measure to determine if discrepancy lies among this population and lapse of time. Third, patients who experience TLE may experience reorganization of the brain after a seizure, thus skewing results for other patient populations. The only way to combat this for visual memory tasks is to test the measure on a wide array of sample populations. The PNMT has been assessed on normal population and abstinent alcoholics. The present study will collect data on TLE patients, which will combat issues surrounding verbal and visual memory impairment with this population. To further this measure, it should be given to an expansive clinical population. Fourth and fifth, confounds occur when motor abilities are taxed when performing visual tests. The PNMT eliminates motor function without the need to utilize motor skills to perform the task (Heilbronner, 1992).

Previous studies conducted to validate the PNMT have all found a preference to the PNMT compared to the Biber Figure Learning Test, RAVLT, and ROCF. The Biber Figure Learning Test was found to be mediated by verbal components even though it is thought of as a nonverbal assessment (Teaford, 2016). The PNMT was found to be a better nonverbal memory assessment than the ROCF due to the participants being able to learn the stimuli better, thus allowing a more valid learning curve. Additionally, participants with impaired motor skills may naturally perform worse on the ROCF due to the drawing component of the test. Since the PNMT does not require motor skills to perform the task, this bias is eliminated (Kociuba, 2011). Results showed for a study comparing ROCF, RAVLT, and PNMT, that ROCF and RAVLT are mediated by education level. However, the PNMT was not affected by education level, therefore it can provide a true estimate of nonverbal memory ability without the influence of external factors (Phelan, 2013). From these previous studies, the PNMT can be considered a better measure of nonverbal memory compared to the Biber Figure Learning Test and ROCF.

1.10 Present Study

The present study had six goals:

Goal 1: The PNMT performance should correlate with performance on the ROCF due to both measures assessing nonverbal memory.

Hypothesis 1: Performance on PNMT will significantly correlate with performance on the ROCF.

Goal 2: The PNMT and ROCF should not correlate with the RAVLT due to the RAVLT assessing verbal memory.

Hypothesis 2: Performance on PNMT and ROCF will not significantly correlate with performance on the RAVLT.

Goal 3: The PNMT will exhibit the same logarithmic learning curve as the RAVLT.

Hypothesis 3: The PNMT and RAVLT will both produce a r^2 greater than 0.80 on the logarithmic learning curve.

Goal 4: Participants with right hemispheric damage should perform worse on the PNMT and ROCF, while left hemispheric damage should perform worse on the RAVLT, thus indicating the validity that the PNMT truly measures nonverbal memory.

Hypothesis 4: Participants with right hemispheric damage will correlate at the 0.80 level with performance on the RAVLT, while participants with left hemispheric damage will correlate at the 0.80 level with performance on the PNMT and ROCF.

Goal 5: Determine the specificity and sensitivity of the PNMT in detecting left and right hemispheric damage.

Hypothesis 5: The PNMT should be highly sensitive and specific in identifying participants who have left and right hemisphere impairment.

Goal 6: Participants with left hemispheric damage should recall local items better than global items, while participants with right hemispheric damage should recall global items better than local items on the ROCF.

Hypothesis 6: Participants with left hemispheric damage will correlate at the 0.80 level or higher with performance of local items, while participants with right hemispheric damage will correlate at the 0.80 level with performance of global items.

Chapter II

METHODS

2.1 Participants

Seventeen participants, (11 Female), were recruited from Ohio and Michigan by Craigslist advertisements, fliers, Research Match, and through the Cleveland Epilepsy Association. Participants ages ranged from 23 – 70, with a mean of 46.35 years of age (SD = 13.47). Years of formal education ranged from 8-18, with a mean level of education of 12.71 years (SD = 2.78). The various ethnicities of the sample included: 9 White/Caucasian, 6 Black/African American, and 2 Hispanic/Latino people. Breakdown of type of epilepsy within the population collected is shown in Table I.

Three participants were not included in the study. Two participants did not complete testing, the other failed the informed consent quiz due to severe cognitive impairment.

Table I.

Location and Epilepsy Type Collected in Sample

Location	Type of Epilepsy
Unknown	Photosensitive Seizures
Bilateral	Absence Seizures, Temporal Lobe Epilepsy, Frontal Lobe Epilepsy
Left	Frontal Lobe Epilepsy
Unknown	Generalized Tonic-Clonic Seizures
Right	Temporal Lobe Epilepsy
Unknown	Absence Seizures, Complex Partial Seizures
Bilateral	Refractory Seizures
Bilateral	Generalized Seizures
Unknown	Hypothalamic Hematoma
Right	Generalized Tonic-Clonic Seizures
Unknown	Simple Partial Seizures, Catamenial Epilepsy
Right	Temporal Lobe Epilepsy
Bilateral	Temporal Lobe Epilepsy
Right	Complex Partial Seizures, Temporal Lobe Epilepsy
Unknown	Refractory Seizures, Absence Seizures, Temporal Lobe Epilepsy
Left	Refractory Seizures, Temporal Lobe Epilepsy
Left	Generalized Tonic-Clonic Seizures

N=17

2.2 Measures

Rey Auditory Verbal Learning Test

The RAVLT was used in comparison to the PNMT because both assessments use learning curves to determine performance of memory and learning, but the RAVLT assesses verbal memory rather than visual; as such it is a good comparison. The test consists of 15 nouns that is read aloud to the participant with one second between each word. The words are read aloud for five consecutive trials, after each reading for each trial, the participant is asked to recall as many words as he/she can remember. Before the sixth trial, there is an interference list read aloud to the participant comprised of fifteen words. The sixth trial consists of asking the participant to recall the list of words from the original list. Following a thirty-minute delay period, the participant is asked to recall as many words from the original list as possible. The last task is a recognition list that is read aloud to the participant. The participant must determine which words were on the original list and ignore the rest of the words (Rosenberg, Ryan, & Prifitera, 1984).

Rey-Osterrieth Complex Figure

The ROCF was used to assess the validity of the PNMT on this population since both assessments measure visual memory. In order to administer the test, a picture is presented to the participant and is asked to copy it while viewing it. Then, the picture is taken away and the participants is asked to reproduce the image from memory immediately. After a 3 minute and 20-minute delay period, the participant was asked to reproduce the image from memory again to create three scores (Hubley & Tremblay, 2002).

Poreh Nonverbal Memory Test

A description of the administration of the PNMT is as follows. A blue screen with white boxes in various patterns is presented to the examinee. There is a total of nine designs, and each design is shown over a period of five trials. The task involves the examinee choosing one square at a time until the correct square is chosen. The examinee must remember the location of each correct square for each of the nine designs. Once all five trials have been presented, a 30-minute delay is given. After the delay, the examinee is presented with the task for one more trial.

Computer Assisted Software

The PNMT and RAVLT was administered through computer assisted software. The RAVLT software included audio that read the lists of words for all trials. All measures used software for scoring. The ROCF software allowed the examiner to input the data at the same time the participant was drawing the figure, then Savage, Bennet-Levy, copy, and delay scores were calculated. RAVLT scores were attained through the software by adding total number of words recalled, while PNMT software added the total number of times the participant clicked on the squares before finding the red square (Poreh, 2012; Poreh & Shye, 1998; Poreh, Sultan, & Levin, 2012).

2.3 Procedure

After participants were recruited, they were given a consent form to read and sign. Following the reading and signing of the informed consent form, a form assessing their capacity of consent was carried out. This was followed by an informed consent quiz. See

Figures 8 and 9. If the participants had the capacity to consent and passed the informed

consent quiz, participants were given three measures to complete during the session.

The first test administered was the PNMT, which was administered via computer.

For the first trial, the individuals randomly clicked on white boxes, until a white box

turned red. Participants then should have tried to memorize the location of the red box for

each figure. There is a total of nine arrangements, with five trials for each arrangement. A

30-minute delay trial is given after the fifth trial.

The second test administered was the RAVLT, which is comprised of 5 trials of

recalling nouns from a list that was read aloud to the participant. After the 5 trials, a

different list is read and recalled, then the participant was tested on the original list

presented. Following a 30-minute delay period, the participant was asked to repeat the

first 15 nouns. The last task was for the participant to recognize which nouns came from

the original list based on a list with both sets of nouns on it.

The third test was the Rey-Complex Figure, which involves presenting a complex

figure to the participants and asking them to draw it to the best of their ability, followed

by a drawing immediately after the first based off memory, then, following a 3-minute

delay period where the participant was filling out the demographic questionnaire

(described below, See Figure 10), the participant is asked to draw the figure from

memory. The final portion of the test is a drawing from memory after a 20-minute delay

period.

The demographic questionnaire asks questions relating to the participant's age,

location of birth, gender, race/ethnicity, handedness, level of education, marital status,

employment status, primary language, type of epilepsy diagnosed, location of seizures,

age of onset, seizure frequency, medication, side effects of medication, surgery history related to epilepsy, and history of concussion. See Figure 10 for further information.

After completing the 20-minute delay trial of the ROCF, the participant was asked if they had any questions, then handed a copy of the consent form, while informing them if they thought of any questions, they could contact the researchers through the contact information provided on the form.

The study was approved by the Cleveland State University Institutional Review Board and all study participants provided written informed consent. Data was collected between June 2016 through November 2016.

Chapter III

RESULTS

3.1 Power Analysis

A Power Analysis was conducted to determine if the sample size (N=17) was adequate to determine an effect using G*Power 3.1.9.2. Using a post-hoc analysis with one-tail, correlational t-test, effect size was determined to be 0.61 due to a coefficient of determination = 0.7810, resulting in enough power to detect a large-size effect of 0.9999.

3.2 General Descriptive Analyses

All analyses were performed with SPSS version 22 software or Microsoft Excel 2016 Edition. General descriptive statistics were computed, including the mean, standard deviation, skewness, and kurtosis for the PNMT, RAVLT, and ROCF.

3.2.1 Poreh Nonverbal Memory Test

Descriptive statistics were analyzed for the PNMT. PNMT data includes the total

number of times it took the participants to find the red square for each trial. Table II show

that there is a slight negative skew with each successive trial suggesting the participants

were not learning the material on the immediate recall, but performed better on the delay

recall trial.

Table II.
PNMT Descriptive Statistics

	Minimum	**Maximum**	**Mean**	**Std. Dev**	**Skewness**	**Kurtosis**
PNMT 1	37	64	48.4118	7.12442	.511	-.112
PNMT 2	23	60	40.8824	10.19732	.061	-.543
PNMT 3	22	52	38.0000	9.43398	-.072	-.900
PNMT 4	16	54	37.4706	10.16192	-.340	.236
PNMT 5	13	56	34.6471	14.06210	-.091	-1.131
PNMT Delay	10	59	33.0588	12.65144	.056	-.256
PNMT Pure Learning	-34	5	-13.7647	13.16971	.015	-1.285
PNMT Total	125	259	199.4118	39.06734	-.401	-.568

N=17

A two-tailed, Spearman correlation was conducted to determine if any effects existed for the

PNMT in relation to age and education, see Table III.

Table III.

Spearman Correlation of Age and Education Effects on PNMT

	PNMT Pure Learning	PNMT Delay	PNMT Total
Age	.355 (p=.162)	.191 (p=.464)	.308 (p=.230)
Education	-.402 (p=.110)	**-.580 (p=.015)***	**-.660 (p=.004)****

Note. * Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

One-Way ANOVA was conducted to examine ethnicity and gender effects on PNMT; see

Table IV and V.

Table IV.

One-Way ANOVA for Gender on PNMT

	df	F	p
PNMT Pure Learning	1, 15	.039	.846
PNMT Delay	**1, 15**	**4.944***	**.042**
PNMT Total	1, 15	2.128	.165

Note. * Significance at the 0.05 level.

Table V.
One-Way ANOVA for Ethnicity Effects on PNMT

	df	*F*	*p*
PNMT Pure Learning	2, 14	3.136	.075
PNMT Delay	2, 14	1.574	.618
PNMT Total	2, 14	.498	.242

3.2.2 Rey Auditory Verbal Learning Test

 Descriptive statistics were calculated for each trial on the RAVLT, where scores are a total number of words recalled. Results show there is a strong negative skew with each successive trial suggesting participants did not remember the material for immediate recall, but a positive skew on the delay trial means they performed better with recall of information. A strong negative, leptokurtic skew is noted for the Recognition trial as well, indicating participants performed better on recognition comparatively to other trials. See Table VI for more information.

Table VI.
RAVLT Descriptive Statistics

	Minimum	Maximum	Mean	Std. Dev	Skewness	Kurtosis
RAVLT 1	1	8	5.2941	2.02376	-.404	-.636
RAVLT 2	3	13	8.4706	2.78652	-.377	-.614
RAVLT 3	4	13	9.5294	2.83103	-.335	-1.021
RAVLT 4	4	14	9.7059	3.09767	-.188	-.862
RAVLT 5	3	15	10.4706	3.18429	-.871	.351
RAVLT Interference	1	9	5.1176	2.39485	-.250	-1.201
RAVLT Post Interference	4	13	8.4118	2.67065	-.168	-.709
RAVLT Delay	3	14	8.4118	2.62342	.007	.630
RAVLT Recognition	7	15	13.0000	2.03101	-1.776	4.082
RAVLT Pure Learning	1	9	5.1765	2.15741	-.046	-.304
RAVLT Total	15	60	43.4706	12.91374	-.572	-.290

N=17

A two-tailed, Spearman correlation was conducted examining age and education effects on RAVLT performance, see Table VII.

Table VII.
Spearman Correlation of Age and Education Effects on RAVLT

	RAVLT Pure Learning	RAVLT Post Interference	RAVLT Delay	RAVLT Recognition	RAVLT Total
Age	-.177 (p=.496)	-.182 (p=.485)	-.246 (p=.341)	-.295 (p=.250)	-.020 (p=.940)
Education	.293 (p=.254)	.011 (p=.966)	.176 (p=.499)	-.242 (p=.348)	.114 (p=.664)

A One-Way ANOVA was performed to examine gender and ethnicity effects on RAVLT

performance. See Tables VIII and IX.

Table VIII.
One-Way ANOVA of Gender Effects on RAVLT

	df	F	p
RAVLT Pure Learning	1, 15	.223	.643
RAVLT Post Interference	1, 15	.008	.932
RAVLT Delay	1, 15	.083	.778
RAVLT Recognition	1, 15	.238	.633
RAVLT Total	1, 15	.002	.965

Table IX.

One-Way ANOVA of Ethnicity Effects on RAVLT

	df	*F*	*p*
RAVLT Pure Learning	2, 14	.103	.903
RAVLT Post Interference	2, 14	.548	.590
RAVLT Delay	2, 14	.306	.741
RAVLT Recognition	2, 14	3.254	.069
RAVLT Total	2, 14	.900	.429

3.2.3 Rey-Osterrieth Complex Figure

　　　Descriptive statistics were conducted for ROCF. Results show a strong negative

skew for copy score, but a positive skew on the recall trials suggestive of better

performance on recall than copy. See Table X for more details.

Table X.
ROCF Descriptive Statistics

	Minimum	Maximum	Mean	Std. Dev	Skewness	Kurtosis
ROCF Savage	0	6	2.6471	1.76569	.226	-.703
ROCF Bennet-Levy	7	27	16.9412	5.48259	-.248	-.495
ROCF Copy	8	36	27.7353	7.58930	-1.046	1.331
ROCF 3min Delay	6	26	14.5294	6.34791	.494	-.896
ROCF 20 min Delay	6	27	15.6765	6.88282	.267	-1.308

N=17

A two-tailed, Spearman correlation was used to determine if age and education effected

ROCF performance, see Table XI.

Table XI.

Spearman Correlation of Age and Education Effects on ROCF

	ROCF Savage	ROCF Bennet-Levy	ROCF Copy	ROCF 3 min Delay	ROCF 20 min Delay
Age	-.344 (p=.177)	-.308 (p=.229)	.016 (p=.951)	-.240 (p=.353)	-.400 (p=.112)
Education	**.629 (p=.007)****	**.566 (p=.018)***	**.703 (p=.002)****	.290 (p=.259)	.498 (p=.042)

Note. * Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

One-Way ANOVA was conducted to examine gender and ethnicity effects on ROCF, see

Tables XII and XIII.

Table XII.
One-Way ANOVA of Gender Effects on ROCF

	df	*F*	*p*
ROCF Savage	**1, 15**	**7.086***	**.018**
ROCF Bennet-Levy	**1, 15**	**6.413***	**.023**
ROCF Copy	1, 15	4.370	.054
ROCF 3 min Delay	1, 15	1.211	.288
ROCF 20 min Delay	1, 15	1.870	.192

Note. *Significance at the 0.05 level.

Table XIII.

One-Way ANOVA of Ethnicity Effects on ROCF

	df	*F*	*p*
ROCF Savage	2, 14	.317	.734
ROCF Bennet-Levy	2, 14	1.247	.317
ROCF Copy	**2, 14**	**6.822****	**.009**
ROCF 3 min Delay	2, 14	1.262	.313
ROCF 20 min Delay	2, 14	1.432	.272

Note. **Significance at the 0.01 level.

3.3 Hypothesis 1

Hypothesis 1: Performance on PNMT will significantly correlate with performance on the ROCF.

A one-tailed, Spearman correlation was used to compare PNMT delay trial and delay trials of the ROCF. Results in Table XIV show these tests are significantly, negatively correlated.

Table XIV.

Spearman Correlations of PNMT and ROCF

	PNMT Delay
ROCF 3 min Delay	**-.771 (p=.000)***
ROCF 20 min Delay	**-.842 (p=.000)***

Note. *** Correlation is significant at the 0.001 level (1-tailed).

3.4 Hypothesis 2

Hypothesis 2: Performance on PNMT and ROCF will not significantly correlate with performance on the RAVLT.

Using a one-tailed, Spearman correlation, Table XV shows RAVLT delay and ROCF delay scores significantly correlate. When PNMT, RAVLT, and ROCF scores were controlled for education, gender, and ethnicity effects results remained unchanged.

Table XV.

Spearman Correlations of RAVLT, PNMT, and ROCF

	PNMT Trial 1	PNMT Pure Learning Trial 5- Trial 2	PNMT Delay	PNMT Total	ROCF 3 min Delay	ROCF 20 min Delay
RAVLT Trial 1	-.115 (p=.330)					
RAVLT Pure Learning Trial 5 – Trial 2		-.013 (p=.480)				
RAVLT Delay			-.353 (p=.082)		**.571 (p=.008)****	**.504 (p=.020)***
RAVLT Total				-.238 (p=.179)		

Note. * Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

3.5 Hypothesis 3

Hypothesis 3: The PNMT and RAVLT will both produce a r^2 greater than 0.80 on the logarithmic learning curve.

A logarithmic learning curve was calculated with Excel using the equation provided in Poreh (2005). Results of immediate trials for PNMT show $R^2 = 0.9676$, which indicates the PNMT is a good measure of nonverbal learning. See Figure 1 for further information.

Poreh Nonverbal Memory Test

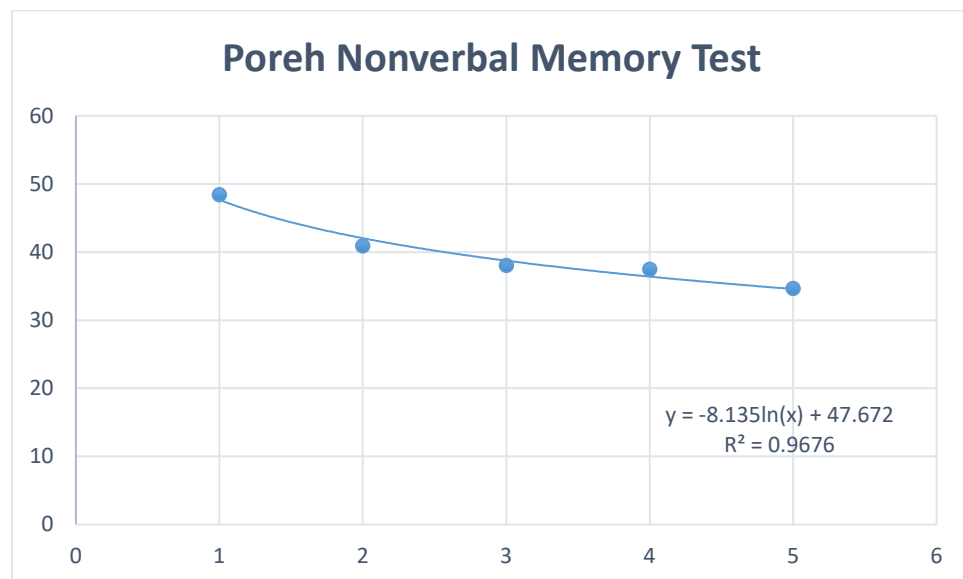$y = -8.135\ln(x) + 47.672$
$R^2 = 0.9676$

Figure 1. *Logarithmic Learning Curve of Poreh Nonverbal Memory Test*

A logarithmic learning curve was calculated with Excel using the equation provided in Poreh (2005). Results of immediate trials for RAVLT show $R^2 = 0.9478$, which indicates the RAVLT is a good measure of verbal learning. See Figure 2 for further information.
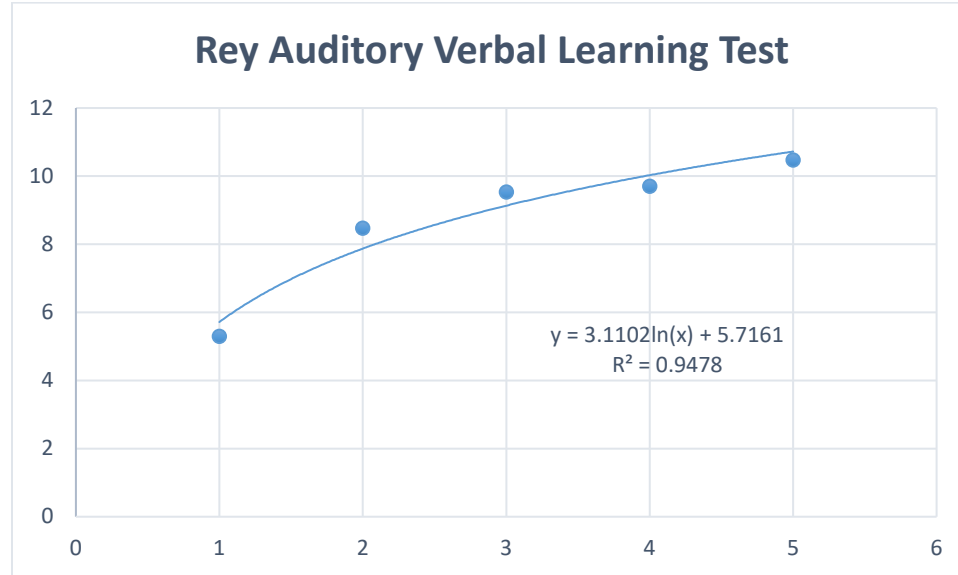
Figure 2. *Logarithmic Learning Curve of Rey Auditory Verbal Learning Test*

3.6 Hypothesis 4

Hypothesis 4: Participants with right hemispheric damage will correlate at the 0.80 level with performance on the RAVLT, while participants with left hemispheric damage will correlate at the 0.80 level with performance on the PNMT and ROCF.

A one-tailed, partial correlation was performed controlling for Gender, Education, and Ethnicity. Results show signification correlation for Location of Epilepsy (Right, Left, Bilateral) for PNMT Delay trial, ROCF copy, RAVLT post-interference, RAVLT delay, and RAVLT total. See Table XVI for more information.

Table XVI. *Partial Correlation Controlling for Gender, Education, and Ethnicity When Examining Left, Right, Bilateral Epilepsy on PNMT, ROCF, and RAVLT*

	Location of Epilepsy
PNMT Pure Learning (5-2)	-.008 (p=.492)
PNMT Delay	**.820 (p=.006)****
PNMT Total	.597 (p=.059)
ROCF Copy	**.678 (p=.032)***
ROCF 3 min Delay	-.434 (p=.142)
ROCF 20 min Delay	-.520 (p=.093)
RAVLT Pure Learning (5-2)	-.428 (p=.145)
RAVLT Post Interference	**-.717 (p=.023)***
RAVLT Delay	**-.731 (p=.020)***
RAVLT Recognition	-.468 (p=.121)
RAVLT Total	**-.786 (p=.010)***

Note. * Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

A one-tailed, Spearman correlation was performed examining the correlations between

ROCF Savage and Bennet-Levy scores when compared to PNMT, ROCF, and RAVLT.

Results show Savage and Bennet-Levy scores significantly correlate with all three

measures. See Table XVII for more information.

Table XVII. *Spearman Correlation Examining ROCF Savage and Bennet-Levy in Comparison to PNMT, ROCF, and RAVLT*

	ROCF Savage	ROCF Bennet-Levy
PNMT Pure Learning (5-2)	-.193 (p=.229)	**-.436 (p=.040)***
PNMT Delay	**-.578 (p=.008)****	**-.756 (p=.000)*****
PNMT Total	**-.585 (p=.007)****	**-.643 (p=.003)****
ROCF Copy	**.553 (p=.011)***	**.626 (p=.004)****
ROCF 3 min Delay	**.436 (p=.040)***	**.682 (p=.001)****
ROCF 20 min Delay	**.627 (p=.004)****	**.791 (p=.000)*****
RAVLT Pure Learning (5-2)	**.550 (p=.011)***	.175 (p=.251)
RAVLT Post Interference	.390 (p=.061)	.295 (p=.125)
RAVLT Delay	.365 (p=.075)	.287 (p=.132)
RAVLT Recognition	-.093 (p=.361)	.155 (p=.277)
RAVLT Total	.239 (p=.178)	.284 (p=.135)

Note. * Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).
*** Correlation is significant at the 0.001 level (1-tailed).

A one-tailed, partial correlation was performed controlling for executive function with

ROCF Savage and Bennet-Levy scores. Results showed a significant difference between

left and right hemisphere impairment with ROCF Copy, RAVLT Post Interference,

RAVLT Delay, and RAVLT Total. See Table XVIII for further information.

Table XVIII. *Partial Correlation Controlling for ROCF Savage and Bennet-Levy Scores When Examining Left, Right, Bilateral Epilepsy on PNMT, ROCF, and RAVLT*

	Location of Epilepsy
PNMT Pure Learning (5-2)	-.159 (p=.341)
PNMT Delay	.151 (p=.349)
PNMT Total	.054 (p=.445)
ROCF Copy	**.747 (p=.010)***
ROCF 3 min Delay	.392 (p=.149)
ROCF 20 min Delay	.314 (p=.205)
RAVLT Pure Learning (5-2)	-.521 (p=.075)
RAVLT Post Interference	**-.662 (p=.026)***
RAVLT Delay	**-.636 (p=.033)***
RAVLT Recognition	-.122 (p=.377)
RAVLT Total	**-.621 (p=.037)***

Note. * Correlation is significant at the 0.05 level (1-tailed).

3.7 Hypothesis 5

Hypothesis 5: The PNMT should be highly sensitive and specific in identifying

participants who have left and right hemisphere impairment.

A ROC curve was calculated using a pure learning trial (PNMT Trial 5 minus PNMT

Trial 1) of the PNMT compared to left, right, or bilateral hemispheric damage. Figure

3 shows Pure Learning is not sensitive and specific when detecting left and right

hemispheric damage.

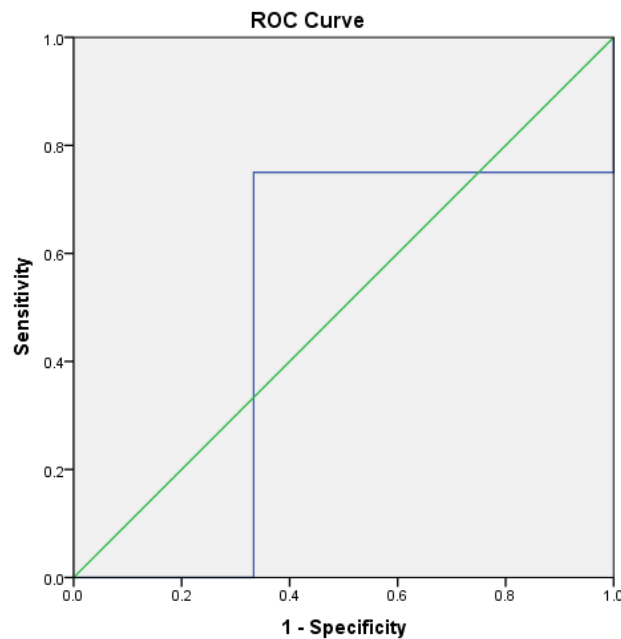Figure 3. *ROC Curve of Pure Learning Compared to Right and Left*

In order to examine whether PNMT total score was sensitive and specific to detect

left, right, or bilateral hemispheric damage, a ROC curve was calculated. Figure 4

shows PNMT total is not a highly sensitive or specific measure in detecting deficits.
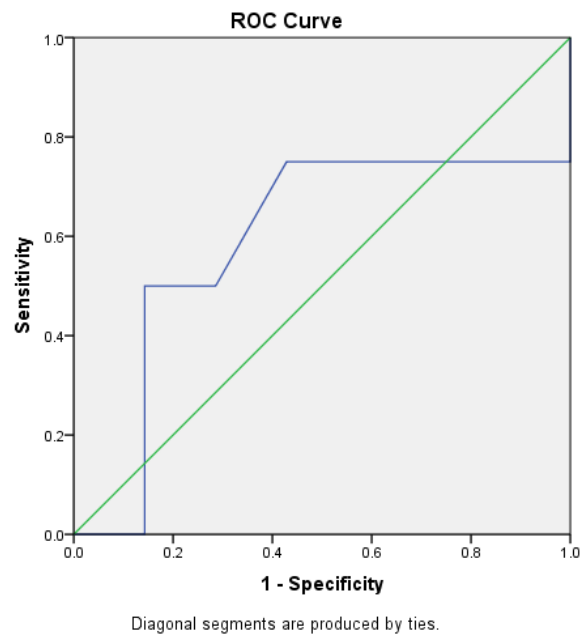
Figure 4. *ROC Curve of PNMT Total Compared to Right, Left, and Bilateral*

The PNMT delay trial is shown to not be highly specific or sensitive in detecting right and left hemispheric impairment, shown in Figure 5.
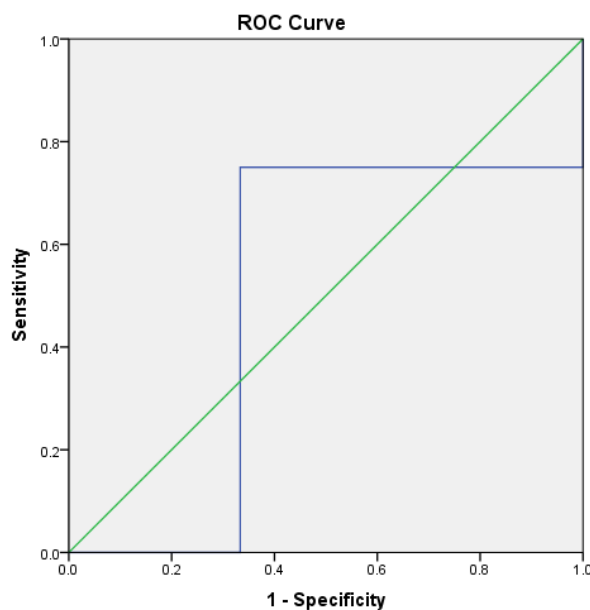
Figure 5. *ROC Curve of PNMT delay Compared to Right and Left*

Since the ROCF is known to be a sensitive and specific measure for detecting left, right, and bilateral deficits (Fedio & Mirsky, 1969; Delaney et al., 1980), a ROC curve was examined to see whether this sample replicated previous results. In Figure 6, it is shown that this sample does not find the ROCF measure to be specific and sensitive in detecting right, left, or bilateral function.
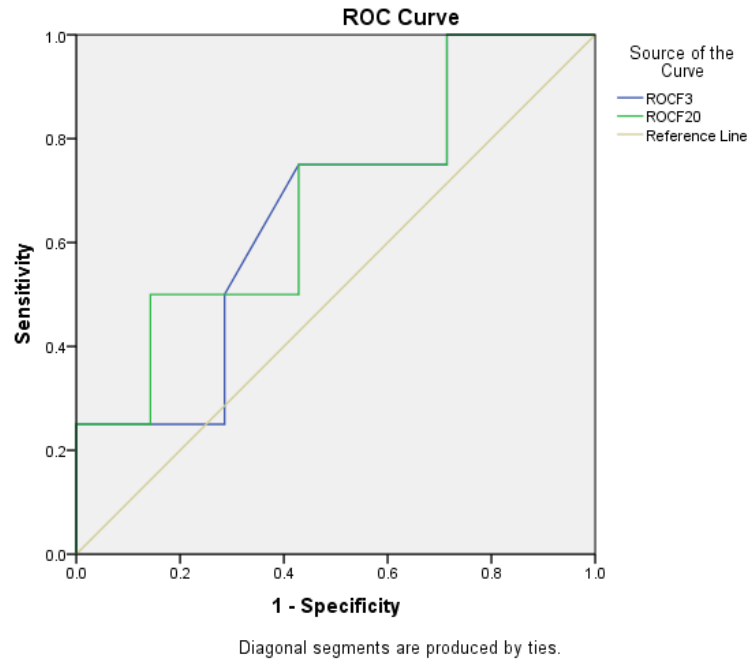
Figure 6. *ROC Curve of ROCF 3-minute and 20-minute delay Compared to Right, Left, and Bilateral*

3.8 Hypothesis 6

Hypothesis 6: Participants with left hemispheric damage will correlate at the 0.80 level or higher with performance of local items, while participants with right hemispheric damage will correlate at the 0.80 level with performance of global items.

A one-tailed, partial correlation was performed controlling for ROCF Savage and Bennet-Levy scores, which shows a significant difference on location of epilepsy (left, right or bilateral hemisphere) and global versus local features for ROCF copy global features. However, no other global and local features apart from ROCF copy were found. See Table XIX for more information.

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Table XIX.

Partial Correlation Controlling for ROCF Savage and Bennet-Levy Scores Examining
ROCF Global and Local Features When Compared to Location of Epilepsy

	Location of Epilepsy
ROCF Copy Global	**.693 (p=.019)***
ROCF Copy Local	.515 (p=.078)
ROCF 3 min Delay Global	.454 (p=.110)
ROCF 3 min Delay Local	-.435 (p=.121)
ROCF 20 min Delay Global	-.214 (p=.290)
ROCF 20 min Delay Local	-.334 (p=.190)

Note. * Correlation is significant at the 0.05 level (1-tailed).

3.9 Other Analyses

Multidimensional Scaling (MDS) was used to determine if PNMT Pure Learning, PNMT Delay, PNMT Total, RAVLT Pure Learning, RAVLT total, RAVLT Interference, RAVLT Post Interference, RAVLT delay, PNMT total, ROCF Copy, ROCF 3-minute delay, and ROCF 20-minute delay were similar. In Figure 6, a perceptual map is shown of groupings of tests. PNMT total is shown to be on a different dimension than the other cluster of scores.
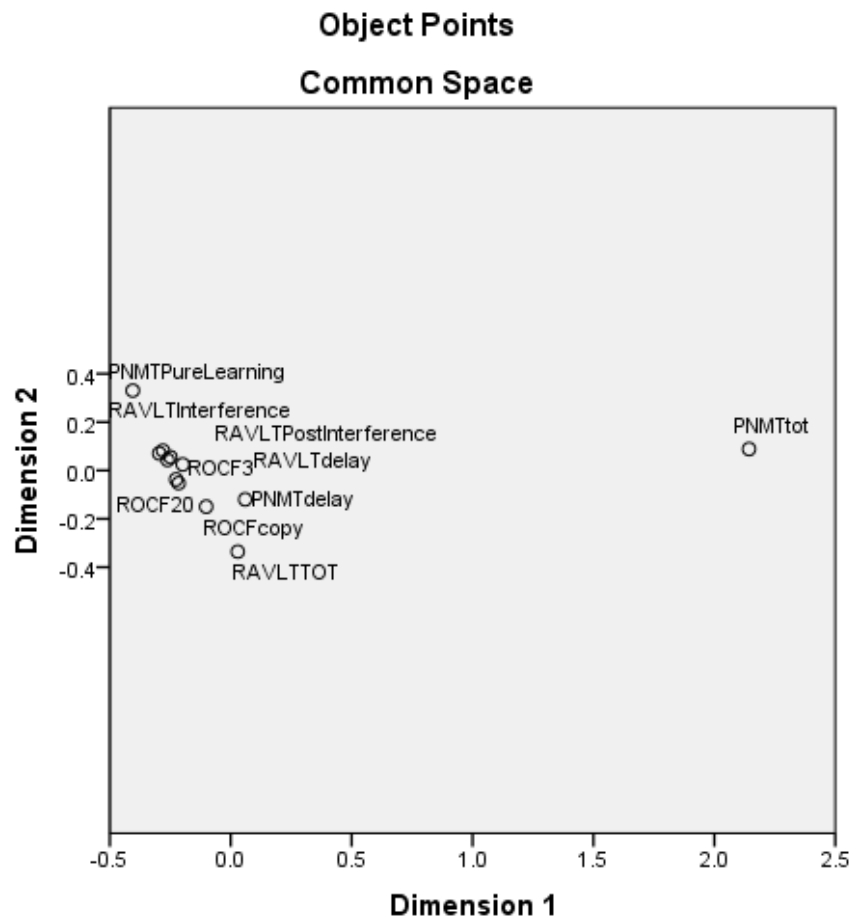
Figure 7. *Perceptual Map of Test Scores*

Chapter IV

DISCUSSION

4.1 Summary of Present Study

The present research is an additional study that is being used to validate the Poreh Nonverbal Memory Test. This study, however, is the first in the set to establish that the PNMT can differentiate between lateralization in the brain through the examination of the test on participants with epilepsy.

Several confounds were found when examining age, gender, education, and ethnicity. PNMT Delay trial exhibited a confound with education, with higher levels of education performing better. PNMT total exhibited a confound with gender, with females performing better than males. ROCF copy correlated with education and ethnicity, where higher levels of education performed better and White/Caucasian performed better than Black/African American and Hispanic/Latino. Executive functioning scores (Savage and Bennet-Levy) on ROCF correlated with gender and education, where females and higher

education levels performed better. However, no confounds were found in recall trials. These results are important to show how education effects performance on PNMT delay, ROCF copy and strategy scores, but ROCF delay scores were not impacted.

The PNMT and ROCF are significantly correlated on several trials indicating the PNMT has similar validity to the ROCF in detecting nonverbal memory. PNMT Pure Learning and ROCF Copy did not correlate, which provides further evidence that PNMT Pure Learning requires memory, while copy is entirely constructional. However, the PNMT and RAVLT are not significantly correlated. The lack of correlation can be interpreted as providing further evidence that the PNMT is a measure of nonverbal memory, while the RAVLT is a measure of verbal memory.

Logarithmic learning curves were calculated for PNMT and RAVLT indicating that both are good measures of learning. Furthermore, these results indicate that the PNMT is able to measure nonverbal learning; a finding that is consistent with previous literature (Kociuba, 2011; Phelan, 2013; Poreh, 2012; Teaford, 2016). As well as, this study has corroborated previous findings that the RAVLT is a measure of verbal learning (Poreh, 2005, 2012).

In order to examine whether the PNMT, ROCF, and RAVLT could detect location of epilepsy, confounds were removed and results show PNMT and RAVLT are able to find a significant difference between lateralization. All three assessments were found to be significantly correlated with executive functioning scores of ROCF; therefore, when these scores were eliminated, results show ROCF and RAVLT being able to discriminate location of epilepsy.

Thus, it provides evidence that these two tests use executive functioning to perform each task, which requires frontal lobe functioning, not temporal lobe (Damasio, Anderson, & Tramel, 2011).

The PNMT and ROCF lacked specificity and sensitivity in order to detect deficits in left and right hemispheric function. While some studies have found that figural reproduction tests, like the ROCF, are sensitive measures in detecting right and left hemispheric damage, (Delaney et al., 1980; Fedio & Mirsky, 1969), other studies have not had similar results (Barr et al., 1997; Chelune et al., 1991; Ivnik et al., 1992). The lack of sensitivity and specificity found may further indicate that visuospatial tasks are a poor indicator of nonverbal memory deficits due to left or right hemisphere impairment, or may be due to a low sample of participants that indicated right or left damage.

When global and local features on the ROCF were examined in comparison to right or left hemispheric damage, results show that ROCF copy global features significantly differs dependent upon lateralization. Previous studies have shown left hemisphere damage exhibits an intact ability to copy global features, but deficits in copying local features (Binder, 1982; Delis, Kramer, & Kiefner, 1988; Delis, Kiefner, & Fridlund, 1988; Poreh & Shye, 1998). This study corroborates previous findings regarding the copy trial. Only two participants had frontal lobe epilepsy, so examining whether recall performance was worse than copying the figure was unable to be performed (Poreh & Shye, 1998).

Multidimensional scaling was used to examine if any differences existing between the scores. Since, PNMT total is different from the other scores, it might be measuring a

different construct. Further research should be conducted regarding this phenomenon to determine if PNMT total is examining total immediate learning.

Lee discusses the issues of inferring temporal lobe dysfunction based on poor memory test performance since attention-concentration deficits and medication side effects may be causing memory impairment (Lee, 2010). To help alleviate confounds due to memory loss caused by outside factors, the patient was asked if he/she experienced any side effects. If so, they were noted and taken into consideration when analyzing data.

4.2 Limitations

Since confounds were found in regard to age, sex, education, and ethnicity effects, this may have caused bias to skew results and cause lack of sensitivity and specificity for both PNMT and ROCF. A random sample was used to select participants in order to attempt to reduce these confounds. With further studies, a high sample size might negate these confounds. However, regardless of confounds, a high correlation between the ROCF and PNMT was still shown regardless of small sample size.

The biggest limitation of this study was the lack of verification of left, right, or bilateral epilepsy. Medical charts were not available to access, so information acquired on location of epilepsies was self-report. Not all participants were aware of location of epilepsies, which decreased the sample size of left (n=3), right (n=4), and bilateral (n=4) lateralization. This lack of information most likely caused lack of sensitivity and specificity for the PNMT and ROCF in detecting lateralization impairment, lack of correlations among PNMT, RAVLT, and ROCF among left and right damage, and lack

of correlation between local and global features and lateralization of ROCF for delay trial.

An important feature of this study is that it did not account for the result of executive functioning playing a role on the three measures used. Since the ROCF and PNMT were expected to only account for memory, specifically nonverbal learning, while RAVLT verbal learning, executive functioning would not appear to play a role with this task. However, ROCF's Savage and Bennet-Levy scores are known for planning and organizational ability, which is a key feature of executive functioning ability (Anderson, Anderson, & Garth, 2001; Deckersbach et al., 2000; Troyer & Wishart; 1997). When compared to the PNMT, it is important to consider executive functioning playing a role for each trial as the participant organizes the figures and planning before pressing the squares in order to accurately determine where the red square can be found.

4.3 Future Directions

In order to further the validity of the PNMT in detecting lateralization, analysis should be conducted on individuals who have unilateral deficits, specifically stroke damage, TBI, or split brain patients, and gain access to medical charts to corroborate self-report on left, right, or bilateral hemispheric damage.

Due to the new finding that executive functioning plays a role in planning and organizational ability on the PNMT, this measure should be compared to executive functioning tasks, specifically Stroop Color-Word Test, Paced Auditory Serial Addition Test (PASAT), Trail Making Test Part B, Tower of London Test, Five-Point Test, Dallas Kaplan Executive Functioning Systems (D-KEFS), Frontal Assessment Battery (FAB), and Ruff Figural Fluency Test.

The examination of place-cells in animal research has given insight into visuospatial maps and memory processes involving navigational abilities (Aggarwal, 2016; Scoville & Milner, 1957), particularly in seizure research (Xianzeng Liu et al., 2003). New studies have started examining place cells in humans instead of animal models through the use of depth electrodes (Niediek & Bain, 2014). Since the PNMT is modeled after the Morris Water Maze, examination of this measure in humans for its visuospatial properties may show that the PNMT is applicable in assessing visuospatial cognitive deficits.

4.4 Conclusion

This study has served to provide additional validity to the PNMT and examine its potential as a diagnostic tool for right and left functioning. The results show the PNMT is comparable to another well-used nonverbal measures in assessing nonverbal memory, and may even be used in place of the ROCF since it does not utilize verbal components. The PNMT has further showed support as a good measure of nonverbal learning and is contrasted to a verbal measure, the RAVLT.

Limitations of the study discussed previously include confounds of age, sex, education, and ethnicity, lack of knowledge of patient's epilepsy type and location, and the total score of PNMT being different than the other scores measured. Additional research is needed to examine how the limitations effected the results.

Further research should continue with impaired right and left hemisphere subjects to establish specificity and sensitivity of the measure, examine the role executive functioning plays in the PNMT, and examine how subjects remember objects in a visuospatial map.

Based off the current and previous research examining the PNMT, further research should be conducted to allow a true understanding of the measure and eventually its use in clinical work in detecting memory, visuospatial, executive functioning, and right and left hemisphere impairments.

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APPENDIX

Capacity to Consent Checklist
"Validity of Poreh Nonverbal Memory Test Explained by Left and Right Temporal Lobe Epilepsy" study

Principal Investigator: Amir M. Poreh, PhD
Investigators: Sarah Tolfo

Patient Name _____

	YES	NO	The patient...
1.			Understands the research project
2.			Recognizes how participation will affect their own care
			Understands the type of treatments involved in the study
3.			Understands the potential consequences of participating
			Understands their right to withdraw from study at any time and receive regular treatment (under non-study, clinical condition)
4.			Understands they have a choice regarding participation

If patient *does not* have the capacity to consent, please comment:

_____

_____

_____

To the best of my knowledge, the above named patient **does / does not** (circle one) have the capacity to consent to participating in the "Validity of Poreh Nonverbal Memory Test Explained by Left and Right Temporal Lobe Epilepsy" study.

Name: _____ Title: _____

Signature: _____ Date: _____

Figure 8. *Capacity to Consent Checklist*

Informed Consent Quiz

Study title: Validity of Poreh Nonverbal Memory Test Explained by Left and Right Temporal Lobe Epilepsy

Please circle the correct answer to the True/False questions. In order to participate, you must answer all of the items correctly. If you do not get all of them correct, you are permitted to retake the quiz.

1. Participation in this study is completely voluntary and I may withdraw at any time. There is no consequence for not participating.

    True   False

2. Blood samples will NOT be taken as part of this study.

    True   False

3. The minimum length of time I will be actively participating in the study is 45 minutes.

    True   False

Figure 9. *Informed Consent Quiz*

Demographic Questionnaire

ID# _____

1. Birth date: _____

2. Where were you born (city/region, country): _____

3. Gender:
   - ☐ Male
   - ☐ Female

4. Ethnicity origin (or Race):
   - ☐ White
   - ☐ Hispanic or Latino
   - ☐ Black or African American
   - ☐ Native American or American Indian
   - ☐ Asian / Pacific Islander
   - ☐ Other _____

5. Handedness:
   - ☐ Left-handed
   - ☐ Right-handed
   - ☐ Ambidextrous

6. Education Level:
   - ☐ Less than High School _____
   - ☐ High School Diploma/GED (circle one)
   - ☐ Some college _____
   - ☐ Associate's Degree
   - ☐ Bachelor's Degree
   - ☐ Graduate School

7. Marital Status:
   - ☐ Single, never married
   - ☐ Married or domestic partnership
   - ☐ Widowed
   - ☐ Divorced
   - ☐ Separated

8. Employment Status:
   - ☐ Employed for wages
   - ☐ Self-employed
   - ☐ Out of work and looking for work
   - ☐ Out of work but not currently looking for work
   - ☐ A homemaker
   - ☐ A student
   - ☐ Military
   - ☐ Retired
   - ☐ Unable to work
   - Occupation (if applicable): _____

9. Primary Language: _____

   If English is not your primary language, how many years have you been speaking English? _____

10. Type of Epilepsy:
    - ☐ Refractory Epilepsy
    - ☐ Photosensitize Epilepsy
    - ☐ Benign Rolandic Epilepsy
    - ☐ Lennox-Gastaut Syndrome
    - ☐ Juvenile Myoclonic Epilepsy
    - ☐ Abdominal Epilepsy
    - ☐ Absence Seizures
    - ☐ Temporal Lobe Seizures
    - ☐ Frontal Lobe Seizures
    - ☐ Other _____

11. Location of Seizures:
    - ☐ Left
    - ☐ Right
    - ☐ Bilateral

12. Age of Onset: _____

13. Seizure frequency: _____

14. Medication(s):
 ☐ Yes   ☐ No
 If yes, please list all current medications:

_____

_____

_____

15. Side Effects of Medication(s):
 ☐ Yes   ☐ No
 If yes, please list all side effects:

_____

_____

_____

16. Have you had surgery for your epilepsy?
 ☐ Yes   ☐ No
 If yes, please describe the surgery.

_____

_____

17. History of Concussions:
 ☐ Yes   ☐ No
 If yes, please list date(s) when occurred, location of brain injury, and symptoms
 experienced when concussion occurred:

_____

_____

_____

_____

_____

Figure 10. *Demographic Questionnaire*