Correlations Among Implicit Memory Measures in Adults with Mild Cognitive Impairment

Taylor D. Lambertus

Senior Honors Thesis

Committee: Glenn E. Smith, Ph.D. (Chair), Shelley C. Heaton, Ph.D. (Member), Jeffrey Farrar, Ph.D. (Member)

University of Florida
Abstract

Implicit memory is our “know how” memory that occurs without conscious awareness. Multiple different subsystems of implicit memory have been identified. Best testing of an individual’s implicit memory functioning should include tests from more than one of these subsystems. Few studies have investigated correlation amongst different implicit memory measures to investigate whether the different implicit memory subsystems should be considered one implicit memory construct or separate systems. This study aimed to investigate correlations amongst different types of implicit memory measures, including a Word Stem Completion Test (WSCT), a Mirror Tracing Task (MTT), and a Serial Reaction Time Task (SRTT), within cognitively healthy older adults and individuals with amnestic Mild Cognitive Impairment (aMCI). In cognitively healthy older adults, we saw some, but not all, implicit memory measures correlate with one another, while in individuals with aMCI we saw no correlations in these same measures. Future investigations into the implicit memory construct in individuals with aMCI should include more implicit memory measures to investigate effects of different memory systems on results, and aims to study instrumentation issues in aMCI populations.
Correlations Among Implicit Memory Measures in Adults with Mild Cognitive Impairment

Introduction

Implicit Memory

Implicit and explicit memory represent the two major ways information is learned and remembered. In the simplest terms, implicit memory can be defined as our learning of “how”, as opposed to explicit memory, our learning of “what”. Developing implicit memories involves unconscious awareness and automatic processing (Evans, 2008; Jacoby, 1991). It was originally believed that implicit memory, which is also referred to as non-declarative memory, included the inability to verbalize the method in which the memory was learned and was only accessible when acting out the learned behavior. We now understand that implicit memory involves both expression through motor action (e.g. behavior) and verbalization, as long as there is still an absence of awareness during the memory formation process (Squire, 1982; Graybiel, 2008).

The current distinction between explicit and implicit memory is in regards to conscious or unconscious awareness of learning during the memory formation process. Another distinction between these two memory systems is their neural correlates; learning through explicit memory relies on the medial temporal lobe, while learning with implicit memory is thought to include the basal ganglia, striatum, and neocortex (Squire, 1992; see Figure 1). The distinctions between 1) conscious versus unconscious awareness of learning, and 2) reliance on the medial temporal lobe versus no reliance on the medial temporal lobe both suggest a dichotomous memory system.

Squire and Morgan (1991) classified subtypes of implicit memory as follows: procedural memory, priming, simple classical conditioning, and non-associative learning. Procedural memory includes tasks of skills or habits, and can sometimes include motor and perceptual elements. Priming is cued recall involving prior exposure to a verbal or visual stimulus that
should promote learning (Wright, 1998). Simple classical conditioning is the pairing of two stimuli in which a response usually elicited by the second stimulus begins to be the response to just the first stimulus. Lastly, non-associative learning is the change in response to a stimulus due to repeated exposure. In this study, we will focus on priming and procedural implicit learning. The variety of subtypes of implicit memory and their neural correlates raise the question of whether these different types of implicit memory (e.g. a motor procedural task versus a verbal priming task) are part of the same implicit memory system or represent different subsystems.

Wright (1998) noted moderate, negative correlations amongst different tests claiming to test implicit memory. Specifically, Wright was interested in studying the relation between three implicit memory measures that tapped into different implicit memory constructs, including verbal priming (assessed with the Word Stem Completion Test; WSCT), perceptual procedural
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(assessed with the Gollin Incomplete Pictures Test; GIPT), and motor procedural (assessed with a Pursuit Rotor Test; PRT). Using Pearson correlations, Wright demonstrated a negative correlation between the GIPT and the PRT, but no other significant relations between measures. Similarly, Desgranges and colleagues (1996) used a correlation analysis to view how various implicit memory tasks correlate with one another. In this study, the perceptual representation system (PRS) was assessed using a word stem completion task (WSCT) and procedural memory was studied using a perceptual-motor maze learning task and a perceptual-verbal mirror reading task. The WSCT (priming) did not correlate with the mirror reading (perceptual-verbal) nor the maze learning (perceptual-motor) task. In addition, the two procedural tasks did not correlate with one another; the authors suggested that the tasks rely on additional cognitive processes outside of the procedural system, such as the motor cortex for the maze learning task, or linguistics and working memory for the mirror reading task. In contrast to what was theorized by Wright (1998), we do not see correlation related to the idea of commonality of additional memory systems resourced. Here, according to Wright (1998), we would see correlation between the WSCT and mirror reading task, due to the common verbal factor between them. Taken together, these studies support the notion of distinct implicit memory subsystems as opposed to one implicit memory construct.

Amnestic Mild Cognitive Impairment

Mild Cognitive Impairment (MCI), is a phase between healthy cognition and dementia in which individuals exhibit cognitive decline. The National Institute on Aging and the Alzheimer’s Association define MCI as: (1) concern regarding a change in cognition, noted by the patient, an informant who knows the patient well, or a clinician, (2) significant impairment in at least one cognitive domain that cannot be accounted to the patient’s age or educational background, (3)
general preservation of independence in functions of daily life, allowing some mild problems with more complex functional tasks, and (4) all cognitive changes still mild as opposed to fully demented (Albert et al. 2011). Neuropsychological scores for those with MCI are expected to be around 1 to 1.5 standard deviations below the mean for their given age and education group. There are different classifications of MCI, based off the cognitive deficits an individual present with. Amnestic MCI (aMCI) is given to an individual solely with memory impairments, while non-amnestic MCI represents individuals who have dysfunction in a cognitive domain that is not memory, such as language or executive functioning (Perri et al., 2005). It is important to differentiate between amnestic versus non-amnestic MCI, as they may reflect different etiologies, trajectories of the disease, and may require different treatment methods.

MCI is given as a diagnosis, rather dementia, to signify when cognitive impairment is not in the range of normal aging. MCI is now being targeted as an early time to begin alleviating symptoms or attempt to avoid further decline. In a summary report of guidelines by Petersen and colleagues (2018), the prevalence of MCI increases with older age and lower educational level. Individuals diagnosed with MCI face increased risk of development to dementia, and the percentage of conversion for those older than 65 was 14.9%. Further, there was a relative risk of 3.3 during the frame of 2-5 years for conversion to all dementias, and a relative risk of 3.0 for diagnosis of Alzheimer’s disease (AD). In four separate studies, Petersen et al. (2018) saw a range of 14.4%-55.6% of individuals diagnosed with MCI converting back to normal cognition. However, 2 of said studies followed up and found that 55%-65% ultimately converted to dementia nonetheless. With no successful pharmacologic treatments, further research into MCI is necessary to reduce conversion to dementia.
AMCI can be attributed to different disease etiologies, such as AD. In AD, the medial temporal lobe is often the first brain area to be affected, resulting in initial declarative memory loss (Tierney et al., 1988). However, as implicit memory tasks do not rely on the medial temporal lobe, implicit memory functioning is expected to remain spared in aMCI. In a study by Perri and colleagues (2005), aMCI subjects showed higher performance on priming compared to normal controls, measured by a WSCT, but lower performance for visual repetition priming, measured with a Fragmented Picture Identification test. Patients with dementia due to AD showed significant impairment on lexical priming tasks (both verbal and visual), but did not show major impairment on a motor learning task (Perri et al., 2005; Heindel et al., 1989). These results highlight studies yielding inconclusive data on how different samples perform across different implicit memory tasks. If our current construct of implicit memory is testing for different systems of memory, or different areas of our brains, how is this reflecting on areas of research using these tasks to analyze decline in cognition in neurodegenerative populations?

The purpose of this study is to analyze the implicit memory construct through the use of three separate implicit memory testing measures: the Word Stem Completion Task (WSCT), the Mirror Tracing Task (MTT), and the Serial Reaction Time Task (SRTT). We are investigating correlations between differing implicit memory tests in populations of cognitively healthy older adults and individuals with aMCI.

**Study Aims and Objectives**

Aim 1. To investigate the implicit memory construct and it’s subsystems within cognitively healthy older adults. It is hypothesized that:

a. Both procedural memory measures, the Mirror Tracing Task (MTT) and the Serial Reaction Time Task (SRTT) are correlated.
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b. Neither procedural memory measure is correlated with the priming measure, the Word Stem Completion Task.

c. None of these implicit memory measures are correlated with the explicit memory measure, the Auditory-Verbal Learning Test (AVLT).

Aim 2. To investigate the implicit memory construct and its subsystems within aging adults with amnestic Mild Cognitive Impairment. It is hypothesized that:

a. Both procedural memory measures, the Mirror Tracing Task (MTT) and the Serial Reaction Time Task (SRTT) are correlated.

b. Neither procedural memory measure is correlated with the priming measure, the Word Stem Completion Task (WSCT).

c. None of these implicit memory measures are correlated with the explicit memory measure, the Auditory-Verbal Learning Test (AVLT).

Methods

The present data has been collected through the PEACEOFMND (Physical Exercise And Cognitive Engagement Outcomes for Mild Neurocognitive Disorder) study (IRB201700004).

Participants

Participants were recruited from University of Florida health clinics (e.g. Memory Disorders Clinic, Psychology clinic, Neuropsychology clinic, Perioperative Cognitive Anesthesia Network (PeCAN)). Patients were either informed of the study at an in-person appointment when given an MCI diagnosis or contacted by mail based off documentation of a recent MCI diagnosis in their medical records. Additional participants are also recruited through flyers given by other physicians to their patients who seem to be eligible for our study, posted in local senior
community centers or other areas targeting older adult populations, or other forms of advertising such as brochures, flyers, newspaper articles and websites. Lastly, information sessions may also be held at the aforementioned community centers or community-dwelling sites. Consent is received at a later time once the patient and their designated cognitively healthy older adult partner agree to participate. After consent, a phone-screening interview is scheduled, and, if the participant is determined to be eligible based on our criteria, a testing visit is scheduled.

There were 100 total participants being analyzed in this study, with 42 males and 58 females. 82 participants identified as white/Caucasian. The remaining included one Hispanic/Latino participant, four African American participants, two Asian/Pacific Islanders, and 11 unidentified individuals. The average age of cognitively healthy older participants was 70.37 years (SD=9.53) (see Table 1). The average age of individuals with aMCI was 74.36 years (SD=6.89). Education in the cognitively healthy older adult group averaged at 16.49 years (SD=2.69). Education in the aMCI group averaged at 16.60 years (SD=2.66). The Modified Telephone Interview for Cognitive Status (TICS-M) was used to determine cognitive ability and eligibility for study. Cognitively healthy older adults averaged 36.76 on the TICS-M (SD=3.79). The aMCI group averaged 28.53 on the TICS-M (SD=4.03).
Table 1
Demographic and Global Cognition of Individuals with Amnestic Mild Cognitive Impairment (MCI) v. Cognitively Healthy Older Adults

<table>
<thead>
<tr>
<th>Variable</th>
<th>Subvariable</th>
<th>aMCI</th>
<th>Healthy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Mean</td>
<td>74.36</td>
<td>70.37</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>6.892</td>
<td>9.534</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>61-89</td>
<td>38-84</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>16.6</td>
<td>16.49</td>
</tr>
<tr>
<td>Education</td>
<td>Std. Dev.</td>
<td>2.658</td>
<td>2.694</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>12-20</td>
<td>10-20</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>28.53</td>
<td>36.76</td>
</tr>
<tr>
<td>TICS-M</td>
<td>Std. Dev.</td>
<td>4.026</td>
<td>3.793</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>21-37</td>
<td>26-44</td>
</tr>
</tbody>
</table>

Eligibility

Participants that are enrolled have a diagnosis of MCI and a cognitively healthy partner, who will serve as an informant as well as a source for cognitively healthy older adult scores to compare with. During the phone-screening interview, the Clinical Dementia Rating scale (CDR) is used to confirm an MCI diagnosis in the participant, as well as the Modified Telephone Interview for Cognitive Status (TICS-M) to determine the cognitive health of the participant’s partner. Inclusion criteria for the MCI patient are: 1) Written informed consent for participation, 2) A formal diagnoses of amnestic MCI (single domain or multi-domain; aMCI) in the last 6 months through neuropsychological evaluation or CDR score of 0 or 0.5 and a TICS-M score of at least 25, 3) at least 50 years old, 4) Not taking or are stable on pain medication and/or nootropic(s) on a dose/frequency for at least 3 months that affects cognitive abilities, and 5) fluent in English. Inclusion criteria for the partner are: 1) written informed consent for participation, 2) at least 21 years old, 3) a TICS-M score of at least 32, and 4) partner is someone who is in contact with the participant at minimum twice weekly. Exclusion criterion for the MCI patient is: 1) MRI contraindications (i.e., ferrous metal in the body, claustrophobia, pregnancy).
Exclusion criterion for both the participant and partner is: 1) Other impairments or deficits that would limit ability to perform tasks or participation in the intervention (physical impairments, language comprehension deficits, significant hearing disturbances).

**Procedures**

The full procedure consists of consent, phone-screening interview, baseline MRI scan and cognitive testing, intervention, booster session and a follow up visit MRI scan and cognitive testing. Coming after written consent, a phone-screening consists of a personal background interview including questions regarding medication use, language barriers, physical abilities, and basic demographic information such as age, gender, etc. Now is also when it is determined whether or not the aMCI patient has any MRI contraindications. All participants (MCI patient and care partner) are administered the TICS-M to screen for cognitive impairment. The CDR is used to assess the aMCI patients, but does involve questions for the care partner as well.

**Measures**

The Rey Auditory Verbal Learning Test (AVLT) was used to measure explicit memory. Tests measuring procedural or implicit memory that are conducted are the Word-Stem Completion Test (WSCT), the Mirror-Tracing Task (MTT) and a Serial Reaction Time (SRT) task.

**AVLT.** The Rey Auditory Verbal Learning Test (AVLT) is used to measure declarative or explicit memory. In this study, explicit learning is measured in two ways. We first look at learning within trial 1 of the AVLT: how many words does the participant remember immediately after hearing the list of 15 words for the first time. Next, we measure learning since trial 1 and through trial 5. We calculate this by multiplying the number of words recalled in trial 1 by five, and subtract this number from the total number of words recalled in trials one through five.
**Mirror Tracing.** A mirror-tracing task is considered a task of procedural memory which also requires motor skill. Participants are presented with a paper with one smaller star within the boundaries of a slightly larger star, leaving a small, half of an inch gap in between. They are asked to repeatedly attempt to draw the shape of a star within the boundaries of the two guiding lines, through the view of a reflection in a mirror. Each trial is timed and ended at a maximum of 5 minutes regardless of completion. Implicit memory is measured in the Mirror Tracing Task by using the slope of time over ten trials.

**Serial Reaction Time.** A serial reaction time task is considered another test of procedural memory, one which involves only a limited motor component. It involves a patterned sequence of 4 different colored circle stimuli, and measures a participant’s reaction time in response to each display of a filled colored circle. There are 7 trial blocks, 6 of which consist of the same pattern, and the 7th changing to a new pattern. The participants are unaware of these blocks and when they move from one trial block to the next, therefore explicitly unaware of any indication of pattern or pattern changing. If implicitly learned, participants should improve by the end of the task, presumably predicting which of four stimuli to choose next, yet still unaware of their learning of any pattern. To confirm a lack of awareness or explicit memory in such a task, the participant is asked, typically at the end, if they recognized any sort of pattern in stimuli presentation, and if so, to explain or represent it. The serial reaction time task is measured in three ways. The acquisition slope measures reaction times over the first 6 trial blocks with the repeating pattern and is therefore thought to reflect pattern learning, while it may also reflect motor learning or task learning more generally. The transfer slope measures reaction times from the 6th block to 7th block during which the participant adjusts to a new pattern, which is thought to reflect pattern learning. Finally, total speed change slope is the measure of median reaction
time between block 1 and block 7 trails, reflecting change in speed between the first and last block, potentially reflecting motor speed change distinct from pattern learning. Each block utilizes the median response time to avoid effect of outliers. The Serial Reaction Time Task is measured by the slope of the median reaction time across acquisition, the first 6 blocks in which participants encounter the same pattern, and transfer, the transition from the sixth to seventh block, in which the pattern changes. Additionally, a slope was calculated based on block 1 and block 7, labeled the total speed change slope.

**Word-Stem Completion Task.** A word-stem completion task is a task of priming. It involves priming the participant with two sets of 13 words by asking the participant to rate each word on a scale of one to five, the aim being unawareness of priming of the participant. The first word on each list of 13 as well as the last two words are not used in the actual task to avoid primacy and recency effects. The remaining ten words on each list are the primed target words. This is followed by word stems being presented, and the participant being asked to fill in the blank by stating a full word that starts with each presented stem. Each trial contains 20 total stems, 10 of which are stems of words used to prime the participant, and the remaining 10 stems corresponding to unstudied baseline words, or non-primed words. For the remaining new stems in each trial, the participants can still respond correctly by finishing a stem with the most common response word. Implicit memory performance is measured using the result of dividing the number of learned target words participants responded with by the number of both learned and unlearned target words that participants responded with. The Word Stem Completion Test was measured by dividing correctly identified primed target words by the total number of target words hit, including learned and unlearned words.
Analyses

Pearson correlation analysis was conducted to examine intercorrelations of implicit memory measures using the MTT, WSCT, and SRTT in order to verify whether the tests that are theoretically of the same memory system are truly testing the same memory system. This will be done separately for each population. Correlations between demographic information and explicit memory measures from the AVLT were also explored. Correlations were ran separately for cognitively healthy older adults and individuals with aMCI. All analyses were conducted using the Statistical Package for Social Sciences (SPSS, Version 25; Armonk reference).

Results

Normality was assessed by inspection of histograms and assessing skewness and kurtosis. Variables that significantly violated the assumption of normality were normalized using Blom’s formula.

Cognitively Healthy Older Adults

In cognitively healthy older adults (see Table 2), a significant correlation was found between SRT transfer slope and MTT slope \((r=.344, p<.05)\). This is in agreement with our hypothesis 1.A., that both procedural memory measures, the Mirror Tracing Task (MTT) and the Serial Reaction Time Task, would be correlated in cognitively healthy older adults.

Regarding hypothesis 1.B., we found that SRT acquisition slope correlated with the WSCT priming score \((r=-.414, p<.01)\), and SRT speed change slope also correlated with the WSCT priming score \((r=-.363, p<.05)\). Therefore, in cognitively healthy older adults we see correlations between priming and procedural tasks, which is incongruent with our hypothesis 1.B. Within test, SRT acquisition slope correlates negatively with SRT transfer slope \((r=-.567, p<.01)\), and SRT acquisition slope correlates with SRT speed change slope \((r=.640, p<.01)\).
Our hypothesis 1.C., stating that no implicit memory measures would be correlated with the explicit memory measure, the Auditory-Verbal Learning Test (AVLT), was congruent with the results.

Regarding correlations with our demographics and cognitive severity measures, we found that in cognitively healthy older adults, age was negatively correlated with SRT transfer slope ($r = -0.407, p<0.05$), and AVLT trial 1 learning ($r = -0.568, p<0.01$). We also found a correlation between healthy TICS-M scores and AVLT learning after trial 1 ($r = 0.409, p<0.01$).

**aMCI**

In individuals with aMCI only (see Table 3), we saw no significant correlations between MTT slope and either the SRT slope or any WSCT measures, nor did our analyses show correlations of SRT slope to any WCST measures. This is discordant with hypothesis 2.A, that both procedural memory measures would be correlated in aMCI, but is in line with hypothesis 2.B., that neither procedural measure would correlate with the priming measure in individuals with aMCI. Within test, we saw correlations between SRT acquisition slope and SRT speed change slope ($r = 0.830, p<0.01$).

In regards to hypothesis 2. C., we found no correlations between any implicit memory measures and either of our explicit memory measures from the AVLT. The AVLT measures, AVLT trial 1 learning and AVLT learning after trial 1, did not correlate with each other in either population.

In the aMCI population, we saw no significant correlations regarding age. We did find a correlation between TICS-M score and AVLT trial 1 learning ($r = 0.560, p<0.01$). There also exists a negative correlation between education and MTT slope ($r = -0.426, p<0.05$).
## Table 2

Correlation Matrix of Cognitively Healthy Older Adults

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Education</th>
<th>TICS-M</th>
<th>AVLT 1</th>
<th>AVLT 2</th>
<th>MTT Slope</th>
<th>SRT Acquisition Slope</th>
<th>SRT Transfer Slope</th>
<th>SRT Speed Change</th>
<th>WSCT Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>-0.092</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TICS-M</td>
<td>-0.03</td>
<td>-0.063</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVLT 1</td>
<td>0.568**</td>
<td>0.249</td>
<td>0.203</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVLT 2</td>
<td>0.037</td>
<td>-0.119</td>
<td>0.409**</td>
<td>-0.285</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTT Slope</td>
<td>-0.284</td>
<td>-0.101</td>
<td>0.093</td>
<td>0.038</td>
<td>0.026</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SRTT Acquisition Slope</td>
<td>0.296</td>
<td>-0.016</td>
<td>0.091</td>
<td>-0.101</td>
<td>-0.212</td>
<td>-0.274</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRTT Transfer Slope</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.344**</td>
<td>-0.567**</td>
<td>1</td>
</tr>
<tr>
<td>SRTT Speed Change</td>
<td>-0.09</td>
<td>-0.009</td>
<td>0.132</td>
<td>0.001</td>
<td>-0.092</td>
<td>-0.037</td>
<td>0.640**</td>
<td>0.102</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WSCT Priming</td>
<td>-0.152</td>
<td>0.036</td>
<td>-0.188</td>
<td>-0.046</td>
<td>-0.144</td>
<td>0.062</td>
<td>-0.414**</td>
<td>0.231</td>
<td>-0.363</td>
<td>1</td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed). Age and Education are represented in number of years. TICS-M: Modified Telephone Interview for Cognitive Status; AVLT: Auditory-Verbal Learning Test; MTT: Mirror Tracing Task; SRTT: Serial Reaction Time Task; WSCT: Word Stem Completion Task.
### Table 3

Correlation Matrix of Individuals with Amnestic Mild Cognitive Impairment (aMCI)

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Education</th>
<th>TICS-M</th>
<th>AVLT 1</th>
<th>AVLT 2</th>
<th>MTT Slope</th>
<th>SRT Acquisition Slope</th>
<th>SRT Transfer Slope</th>
<th>SRT Speed Change</th>
<th>WSCT Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Education</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>TICS-M</td>
<td>-0.233</td>
<td>0.018</td>
<td>1</td>
<td></td>
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<tr>
<td>AVLT 1</td>
<td>-0.184</td>
<td>-0.179</td>
<td>0.560**</td>
<td>1</td>
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<td></td>
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<tr>
<td>AVLT 2</td>
<td>0.04</td>
<td>0.219</td>
<td>0.266</td>
<td>-0.206</td>
<td>1</td>
<td></td>
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<tr>
<td>MTT Slope</td>
<td>-0.325</td>
<td>-0.426*</td>
<td>-0.307</td>
<td>-0.044</td>
<td>-0.323</td>
<td>1</td>
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<tr>
<td>SRT Acquisition Slope</td>
<td>0.064</td>
<td>0.059</td>
<td>-0.032</td>
<td>-0.097</td>
<td>0.041</td>
<td>-0.069</td>
<td>1</td>
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</tr>
<tr>
<td>SRT Transfer Slope</td>
<td>0.113</td>
<td>-0.246</td>
<td>0.177</td>
<td>-0.055</td>
<td>0.213</td>
<td>-0.030</td>
<td>-0.281</td>
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</tr>
<tr>
<td>SRT Speed Change</td>
<td>0.242</td>
<td>0.162</td>
<td>0.041</td>
<td>-0.044</td>
<td>0.18</td>
<td>-0.152</td>
<td>0.830**</td>
<td>0.173</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>WSCT Priming</td>
<td>0.108</td>
<td>0.013</td>
<td>0.020</td>
<td>0.015</td>
<td>-0.156</td>
<td>0.176</td>
<td>0.204</td>
<td>0.18</td>
<td>0.224</td>
<td>1</td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed). Age and Education are represented in number of years. TICS-M: Modified Telephone Interview for Cognitive Status; AVLT: Auditory-Verbal Learning Test; MTT: Mirror Tracing Task; SRTT: Serial Reaction Time Task; WSCT: Word Stem Completion Task.
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Discussion

The aim of this study was to investigate a) if different procedural memory measures are correlated to each other, b) if procedural memory measures correlated with a priming measure, and c) if implicit memory measures correlated with an explicit memory measure. We aimed to do this both in a sample of cognitively healthy older adults and individuals with aMCI. With this, we hoped to discover if the tests we are utilizing are truly testing the same implicit memory system and if this applies to pathological aging populations as well. We intended to find whether correlations would support an implicit memory subsystem approach. Our results did not support the hypothesis that different implicit memory measures would correlate with one another in aMCI populations, as we found no intercorrelations within this group. In our experiment, we found intercorrelations of implicit memory testing in cognitively healthy older adults between both procedural tasks, as well as between procedural and priming tasks. Neither explicit memory measure was correlated with any implicit memory measure. We did not find any intercorrelations of implicit memory testing in individuals with aMCI, nor did we see correlation between explicit and implicit memory measures.

Previous studies investigating correlations among implicit memory testing are sparse. As noted, Wright (1998) and Desgranges et al. (1996), both failed to find correlation between at least two implicit memory measures. Our results in cognitively healthy older adults relate to speculation made by Wright (1998). Wright pointed out a commonality between the two correlating tests in his study: a visual spatial element. We did find a correlation between the MTT and SRT task, which both share a visual/spatial element to them, as well as a more procedural nature in comparison to the WSCT. However, we also see a correlation between measures of the WSCT and the SRT, which do not share this relation, and lack a correlation
between the WSCT and the MTT. In addition, Desgranges et al. (1996) lacked a correlation between WSCT and a mirror reading task, which share the commonality of a verbal component, nor did they find a correlation between a mirror reading task and a maze learning task, which share a perceptual component.

**Recruitment of Memory Systems**

A different framework of memory systems could explain a lack of correlation amongst implicit memory measures, especially in abnormal aging populations such as our aMCI group. The first system of memory typically to degrade in MCI and dementia populations is episodic memory, tested using tests like the AVLT (Jahn 2013, Albert et al., 2011). Semantic memory is affected shortly after, specifically affecting patients’ language through verbal fluency and naming (Jahn 2013). Related, primary motor cortex is affected closer to the later stages of the disease (Hyman et al., 2012). Maybe, WSCT is related most to semantic, and this is why we see no correlation between verbal priming (WSCT) and a motor procedural task (MTT). Individuals with neurodegenerative diseases could be displaying skewed results.

Cabeza and Moscovitch (2013) explain an alternative hypothesis to our current memory system or processing mode frameworks. Their suggestion is that, instead of looking at completely separated systems of memory or processing modes, there may be recruitment of multiple processing components for each memory task, resulting in a variety of combinations for tasks that may even be within the same “memory system.” This leads to different patterns of associations and dissociations between different processing systems or regions of the brain. As mentioned, those with dementia first begin to lose short term or episodic memory, and next lose semantics, with the motor component following behind later in the progression of their disease. It was also noted by Squire (1992) that recruitment of multiple different brain regions even within
different implicit memory tasks exist, notably utilization of the neocortex for priming and perceptual learning, and the striatum for procedural learning of skills and habits. With this in tandem with the Cabeza and Moscovitch model, we can postulate that, while specific regions or processing systems directly related to implicit memory may still be spared, if systems that are additionally recruited for certain memory tasks are negatively affected, analysis may lack intercorrelations of implicit memory tasks. This explains the existence of a correlation between verbal priming and motor procedural memory in cognitively healthy older adults, and a lack thereof in our aMCI population.

An example of this multiple systems hypothesis is the SRT task. Robertson (2007) considers the many outlooks on the task; many deem this test of implicit learning as a motor task, while others consider perceptual skills to be significantly recruited, and many can agree that it is both. The regularity of pattern could be learned perceptually, as participants could be learning to predict where on the screen the visual cue will come next, and some have even shown that this form of skill learning can be supported solely by perceptual learning as opposed to motor learning (Dennis et al., 2006). Alternatively, a given sequence can be learned through motor learning, as participants may learn the pattern through the motor response buttons. It is also noted that motor skill learning on its own is already supported by similar areas of the brain as implicit procedural sequence learning is: the motor cortex teams up with subcortical areas such as the striatum and the cerebellum, while for SRT task performance, the prefrontal cortex, striatum and cerebellum are all critical regions (Keele et al., 2003, Robertson et al., 2001).

Beauregard et al. (2001) investigated the role of semantic memory in a WSCT task in individuals with Alzheimer’s disease. The study determined whether a target item was semantically degraded with a separate measure in a session prior to the one in which the WSCT
task was administered. For each target word, 20 probe questions were asked of the participant, half of which utilized pictures and the remaining ten utilizing the target word itself. Questions either included the picture of the item with four pictures of answer choices, or the target word with four answer choices in the form of a word. AD participants that scored less than 75% on any target word was signified to be semantically degraded on that item. Semantic degradation was later found to be a significant determinant on WSCT priming in those with AD when a deep encoding process was utilized, showing 4.4% priming for semantically degraded words and 13% priming for semantically intact words. A deep encoding process included the participants being asked one question per target word prior to completing the WSCT task, questions such as “Is this native to Canada or is it foreign” or “Can you lift this?” Cognitively healthy older adults were not semantically degraded on any items. Here, the memory impaired group showed decline in an implicit memory task specifically on words in which their semantic memory was degraded. Interference of a separate memory system could explain the results based on this WSCT.

**Instrumentation and Development of Testing Measures**

Another plausible explanation to a lack of correlation of implicit memory testing in aMCI populations can be related to memory deficits and instrumentation of testing. It has been noted that an early loss in MCI and dementia is short term memory loss. If individuals with memory decline are given explicit instructions at the beginning of a given task, is there potential that the participant forgets these instructions at some point during the task? This can be mediated by frequently reminding the participant of the objective of the given task throughout testing. Potential issues with this include: is it written in the instructions to repeat the instructions of the task, and if not, does this change the experience from participant to participant? Second, do the
results of the task or what it is measuring change if we are giving the participant constant reminders on task instructions?

It is also notable to remember that these tasks, most being experimental in aim, have been developed differently amongst researchers over time. The purpose of a task may be to test a certain system of memory, but the differing methods and variables across tasks could lead to equally various results. Therefore, it should be noted that this is a potential confounder when determining whether multiple independently developed tasks are correlated and valid.

Conclusions and Future Study

To gain a comprehensive understanding of the implicit memory construct and its subsystems, further investigation into correlation amongst implicit memory measures in both cognitively healthy older adults and participants with aMCI is critical to our understanding of these testing mechanisms. Future research should aim to investigate potential confounding factors, such as instrumentation issues in aMCI due to short term memory decline. Pursuits should also include additional commonly used measures of implicit memory that include additional secondary memory or cognitive systems, such as the Gollin Incomplete Pictures Test (GIPT) used in Wright 1998, to investigate the effect of additionally recruited memory systems. These further investigations could reveal differing patterns for decline in implicit memory testing in aMCI populations. This would contribute to our understanding of the implicit memory construct and its subsystems in cognitively healthy older adults and individuals with aMCI. Our understanding of the implicit memory construct and its subsystems may have important implications for behavioral interventions that aim to build on implicit memory systems that remain intact as explicit memory deteriorates.
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