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# Imagining a Memory Palace: Method of Loci and the Effect of Object and Spatial Imagery Skill

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IMAGINING A MEMORY PALACE:
METHOD OF LOCI AND THE EFFECT OF OBJECT AND SPATIAL IMAGERY SKILL

by
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Masters Candidate, Louis Varilias, has successfully defended and made the required modifications to the text of the master's thesis for the M.S. during this Spring 2019.

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Abstract

The method of loci is an ancient mnemonic technique. It involves imagining information to be remembered in a visual form, mentally placing those items into an imagined environment, and then mentally traveling within this environment to recall the information. Numerous studies have found that this method is robust and powerful, especially when compared to other mnemonic techniques like verbal rehearsal. Neuroimaging studies have found that using the method of loci recruits regions of the brain that involve spatial processing and episodic memory. However, little research has been done to examine the effects of individual imagery skill when using the method of loci. In particular, object and spatial imagery skill have not been examined separately before. I conducted an experiment with a word list recall procedure to investigate imagery skill and performance using the method of loci. My results showed that scores on an object imagery test predicted recall performance with words. The results also showed that scores on a spatial imagery test predicted quality of serial organization of words.

*Keywords*: method of loci, object imagery skill, spatial imagery skill, episodic memory

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## Introduction

Aristotle wrote in *De Memoria* (trans. 2000) that memory keeps one's past alive. In his view, one sees the past as an image in their mind. This is what one would normally call remembering. He distinguished remembering from recollection. To him, recollection is a more advanced capacity, where one mentally travels through ideas in perhaps a spatial manner. For instance, according to Aristotle, one may naturally travel from the letter 'D' to the letter 'E', then to the letter 'F', in order to remember 'G'. Not surprisingly, memory was not simply a theoretical interest for philosophers. Some people had a practical interest to expand human memory capabilities. This field of thought became known in ancient Rome as the art of memory. The *method of loci* (MoL; Yates, 1966) is one of the most well-known art of memory techniques.

### Method of loci

MoL involves creating an item-to-loci mapping called a *memory palace.* One begins by recalling a route one has traveled through, with its details and features. Then, one visualizes various pieces of information (concrete or abstract) as different items for memorization. Finally, one imagines travelling the route and placing the items at specific spots - similar to Aristotle's conception of recollection. The imagined item often will interact with these spots. Many practitioners in antiquity, such as Cicero, recommend that the interaction or imagined item is bizarre (e.g., I imagine a little green alien eating a banana at the doorway of my house). To recall items, one imagines traveling the route.

Laboratory research has shown that MoL is a highly effective mnemonic technique. For example, one laboratory study systematically compared five different mnemonic techniques: visual imagery (imagining what an item looks like), link (imagining one item on a list interacting with the next item), peg (imagining one item on a list interacting with items on a pre-defined list), rehearsal (verbal method of repeating items on a list), and MoL (Roediger, 1980). Participants were assigned one of these methods to recall three lists of 20 words each. All the visual techniques were superior on average compared to rehearsal. When items could be recalled in any order, link, peg, and MoL were similarly effective. When items had to be remembered in order, MoL was more effective than peg and link, which were equally effective (cf. Wang & Thomas, 2000). This serial-order advantage has been replicated by other laboratory research as well (De Beni and Cornoldi, 1985). In one study, participants memorized a list of 20 word-triplets with either the link method or MoL. Those in the MoL group recalled better the order of the triplets and the order of the words within the triplets. This suggests MoL is useful for both inter- and intra-list serial learning.

Despite its clear benefits for item recall and ordering, why MoL works is still unclear. To figure this out, a conceptual framework developed by Bellezza (1981) helps to analyze mnemonic techniques like MoL. He proposed that mnemonic techniques show a structure that he called cognitive cuing. The structure mediates between a cue to remember, and the information to be remembered. There are two distinct components of cognitive cuing. One is an underlying organizational structure on which to put material to be remembered. This corresponds to an empty memory palace. Another one is encoding, which he specified as transforming information into a new form. This corresponds to placing items in a memory palace. By this reasoning, MoL must be analyzed in terms of two factors: spatial characteristics (organizational structure), and visual characteristics (transforming information to be remembered into a visuospatial form).

**Spatial characteristics**

MoL is not merely an association of two memories. It demands representing spatial relationships insofar as one imagines traveling along a route both at recall and encoding time.

Recent research has shown that spatial information is likely a fundamental aspect of episodic memory (Robin, Wynn, & Moscovitch, 2016). For instance, A study by Robin, Wynn, and Moscovitch (2016) investigated the role of spatial context in episodic memories. This was done by having participants read a five-line narrative about an event. Within the stories, there were familiar or unfamiliar location or person cues. Afterwards, participants described and recalled the events, specifying if they added spatial or person context. Participants tended to add spatial context when spatial context was not specified. They also showed better recall, provided more details, and experienced greater vividness when given spatial cues. Person context was rarely added when not specified, and participant recall did not improve when they were given person cues. The implication is that people tend to encode spatial information so naturally that they do not need to be told to do so.

Considering this study, it appears that spatial information has a privileged status. Familiar spatial locations aid memory and coincide with greater detail and vividness of memories. Spatial information appears so important to episodic memory that spatial context is generated even when the problem at hand does not require it. This idea makes sense, especially when episodic memory is seen as a subcategory of mental time travel (e.g., Suddendorf, Addis, & Corballis, 2009) - if one travels mentally into the past, he or she will have to be located somewhere.

Neuroimaging evidence also provides especially strong support for the role of spatial information in MoL. Memory athletes who competed in the World Memory Championship and other superior memorizers (all but one participant used MoL to perform all of their tasks) showed unique activations in brain regions associated with spatial thinking: the left medial superior parietal gyrus, bilateral retrosplenial cortex, and right posterior hippocampus (Maguire, Valentine, Wilding, & Kapur, 2003). Participants did not show superior cognitive abilities or differences in brain structure compared to controls, so the activations could be attributed to the use of MoL rather than some biological anomaly. In an fMRI study, when participants were trained with MoL, they showed similar functional connectivity profiles as memory athletes, namely in the parahippocampal gyrus and bilateral retrosplenial cortex. Additionally, these participants showed activation in the dorsolateral prefrontal cortex (which is associated with spatial processing and encoding strategies).

Evidence pertaining to the hippocampus further drives the point that MoL makes use of spatial information. The hippocampus is known to encode time in a spatial-like fashion, just as spatial mnemonics recruit the hippocampus. A modified MoL study that used a temporal memory palace provided a recall advantage, albeit not as strong as MoL (Bouffard, Stokes, Kramer, & Ekstrom, 2018). In this sense, spatial encoding occurs with processes that are expected to use the hippocampus. This spatial encoding provides recall advantages.

The apparent ubiquitous use and benefit of spatial information for memory recall is good reason to suppose that spatial information underlies and organizes episodic memory. In fact, Robin (2018), after reviewing her own studies and related neuroimaging literature, proposed just such a theory. She proposes that the construction system (cf. Hassabis & Maguire, 2009) and event memory have a spatial cognitive mechanism in common, the *spatial scaffold*. According to her theory, spatial context affects how memories are organized, how they are retrieved, and how they interfere with one another. The effectiveness of MoL might very well be because it is itself a type of spatial scaffold. However, going by Bellezza's (1981) description of mnemonic techniques, it is necessary to investigate how information to be remembered is transformed or represented on top of a spatial scaffold - in what form is the information available in a memory palace? That form may be image-like.

**Imagery characteristics**

To the extent that MoL requires people to imagine items and loci, it is by definition a visual mnemonic. But the specific ways that imagery influences memory performance - the reason MoL is used at all - is a different issue. There is a rich history of debate about imagery (e.g., Brogaard & Gatzia, 2017), so there is room for considerable nuance in analysis.

Vividness and imageability effects are common in memory studies. In some cases, the vividness of an image in one's mind will help with accurate recall (Marks, 1973). Words rated as more imageable are more easily recalled (e.g., Paivio, Yuille, & Rogers, 1969).

One might expect that because it is a visual mnemonic that requires users to place concretely visualized items into imagine space, MoL simply gains its advantages through imageability effects. Evidently, this is not the case. Despite its superiority to visualization alone, no study has found that high imageability of words enhances recall with MoL (Legge, Madan, Ng, & Caplan, 2012). Similarly, concrete words compared to abstract words help with recall but have no interaction with MoL (Wang & Thomas 2000). To be sure, one may say that MoL pushed imageability to ceiling levels because of how powerful it is. But if there were ceiling effects, then this is reason to think that MoL modulates how participants imagine, or affects something other than qualities intrinsic to an imagined item (e.g., concreteness).

To understand MoL better, comparison with another mnemonic technique may help: the *survival processing* (SP) mnemonic. With this technique, one imagines him or herself in a situation where survival is at great stake, such as being stranded in the African savanna. Items to be remembered are then imagined in that context for the purpose of survival. The available evidence suggests that it is one of the most effective mnemonic techniques (Nairne, Thompson, & Pandeirada, 2007). Although there is no agreed-upon explanation of why it works so well, some possible reasons include encouraging the use of visual images, or encouraging depth of processing for individual items (Burns, Burns, & Hwang, 2011). Recognizing that MoL is also one of the most effective mnemonic techniques, Kroneisen and Makerud (2017) compared both methods. Specifically, they compared SP, MoL, and regular imagery (imagining a word as vividly and detailed as possible) among participants.

Overall, as is usually the case, MoL was always the most effective. However, the most revealing result was that for response time, MoL took the longest, while SP and regular imagery were faster (Kroneisen & Makerud, 2017). The greater reaction time for MoL makes sense, considering the number of steps required to use it. SP has no specific ordering of items, while MoL always does. Whenever one uses MoL, they imagine traveling through an environment. In this sense, a memory palace is necessarily well-ordered every time it is used, but SP serial ordering can be arbitrarily constructed.

If reaction times were a consequence of taking longer to form images, then skill at producing those images might influence reaction time. Consider bizarre imagery research (Kroll, Schepeler, & Angin, 1986), and how bizarreness is a characteristic can increase memorability of information (Seamon, Philbin, & Harrison, 2006). Bizarre images are typically more complex than normal images. In the sense that a bizarre image is meant to be strange or unique compared to how an image usually appears, it is meant to contain more information than a regular image. This parallels how the loci in MoL are more complex than only the association of two items, and how items are supposed to interact with the loci. When memorizing lists of words when imagery is involved, bizarre images require as long as 40 seconds to completely encode and provide recall advantages. These advantages are not apparent when encoding time is 10 or 20 seconds (Campos, Pérez-Fabello, & Gómez-Juncal, 2009). This suggests that the manner and how skillfully (such as speed of imagining) complex information is encoded will affect results from experiments.

**Imagery Skill**

One possible reason for the high performance of MoL is the manner in which participants use imagery. More specifically, MoL depends on spatial and visual characteristics, so greater skill with either characteristic should produce greater recall and greater ability to imagine words as concrete; the more easily one can imagine their set of loci and traveling to them, the greater recall should be. The idea that imagery skill is a causal factor at work stems neatly from the fact that familiar environments have an advantage over unfamiliar environments in MoL by making it easier to generate cues (e.g., Bellezza & Reddy, 1978; Robin & Moscovitch, 2014; Robin et al., 2016). Familiarity itself can be conceptualized as how well one visualizes something (something can be more familiar because one can visualize more details), although the possibility still remains that it is the imageability of familiar environments themselves that matters as opposed to the individual's imagery ability.

There are no studies that have investigated a relationship between imagery skill and MoL. However, a study by Campos and Pérez (1997) investigated a possible relationship between imagery skill and bizarre images. As noted earlier, the visual complexity of bizarre images parallels the complexity of items placed at loci. They studied factors involving associated pair recall, among which included: a) type of image (normal or bizarre), b) interaction between images, and c) imagery ability (measured by the Visual Vividness Imagery Questionnaire [VVIQ]). For recall, three lists were used with 16 pairs of words for each list. Participants were instructed to imagine the words in the pair interacting.

As far as the dependent variables related to visualization, interaction between images seemed to be most important for recall, but only for some of the experiments - the sort of interacting images used in MoL. Imagery skill had no impact on recall, nor did bizarreness impact recall. These results demonstrated how studying imagery and memory together doesn't reveal obvious patterns. One way to study them together more effectively is - as Campos & Pérez (1997) proposed - using new measures of imagery skill.

The earliest evaluation of imagery skill was over a century ago, and often dealt with the vividness of images in the mind's eye. Today, it is frequently measured by the VVIQ (McAvinue & Robertson, 2007, for a review). However, over time, it has proven to be inconsistent when used to analyze imagery skill. After all, vividness is a subjective measure with no corresponding natural criterion to validate a participant's experience. Another major factor to consider is that imagery skill is now understood to be more than a single factor (Burton & Fogarty, 2003; Poltrock & Brown, 1984). It is now apparent that there are differences between spatial imagery (images that represent spatial relations and imagining spatial transformations) and object imagery (images of the details of individual objects; Kozhevnikov, Hegarty, & Mayer, 2002; Kozhevnikov, Kosslyn, & Shephard, 2005; Sheldon, Amaral, & Levine, 2017; Vannucci, Pelagatti, Chiorri, & Mazzoni, 2016).

The Object-Spatial Imagery Questionnaire was developed from this discovery (OSIQ; Blajenkova, Kozhevnikov, & Motes, 2006). Although the questionnaire is a set of self-report questions, it was validated with objective measures. *Spatial imagery skill* (SI) questions correlated with performance on paper folding and mental rotation tests, among others. *Object imagery skill* (OI) questions correlated with performance on a degraded pictures test where an image had to be detected within a poor-quality image. From the available evidence, it appears that one cannot be comparably skilled at spatial and object imagery as measured by the OSIQ; the object and spatial imagery scales are negatively correlated (Aydin, 2018; Blajenkova et al., 2006). As a result, even between individuals, dissociating spatial and object imagers should be straightforward and provide distinct performance patterns. A related questionnaire was developed in order to evaluate the vividness people experience with spatial and object imagery: the Vividness of Object and Spatial Imagery Questionnaire (VOSI; Blazhenkova, 2016). As with all the other studies distinguishing object and spatial imagery from each other, both dimensions were dissociated.

There is minimal research on the object and spatial imagery distinction when it comes to memory. However, current research has promising developments. A study by Aydin (2018) showed importance effects on autobiographical memory. SI scores predicted the number of episodic details about past and future events, such as emotions, thoughts, temporal, or location details. OI scores predicted the phenomenological details of past events, such as number of visual details, but only emotional intensity for future events. Given that MoL uses both spatial imagery and object imagery by virtue of requiring one to imagine both spatial and object information, skill with either could have different effects when separated experimentally.

**The Present Study**

MoL might work so well because it taps into memory processes that involve generating mental images - imagery skill. Object imagery skill may affect remembering words on a list when using MoL because words must be visualized individually and placed at loci. Spatial imagery skill may affect organizing words to be remembered from a list when using MoL because one must mentally navigate through space to proceed through a memory palace as well as imagining the spatial relationships within a memory palace. Although it is already known that spatial and temporal processes assist with memory, it is not known to what extent these processes make use of imagery skill. Another possibility is that images are epiphenomenal with regard to recall (cf. Pylyshyn, 2003), which would make imagery skill irrelevant.

The present study investigated if object and spatial imagery skill could predict memory performance among participants who use MoL to remember a list of words. Specifically, I investigated if OI predicted recall frequency of words, and if SI predicted remembering words in the correct position on the list. To test this hypothesis, it was necessary to demonstrate that OI and SI were conceptually distinct from each other and can describe different behavioral results. Essentially, I investigated the way people imagine things for the purpose of recall, rather than the characteristics of the things they are trying to imagine. Such correlational research would help add to descriptive distinctions within MoL, and perhaps eventually a theoretical explanation of mechanisms and patterns underlying mnemonic devices in general.

## Methods

### Participants

I recruited 71 Seton Hall University students to participate in the study for course credit. The effects of MoL are robust; as few as 14 participants per condition are needed to detect significant effects (De Beni & Cornoldi, 1985). At the same time, as many as 60 have been used to analyze imagery skill preferences (Kozhevnikov et al., 2002). Each participant was tested individually.

### Design

Participants were trained to use MoL. The memory experiment consisted of encoding and recalling a list of words. The focus of the research question was on which imagery factors are relevant for MoL, even if the same factors are involved with other mnemonic techniques.

OI and SI were measured to investigate individual differences in memory performance. I used multiple regression to examine how well OI and SI predicted each aspect of memory performance when using MoL. I also calculated correlations between each memory skill and each imagery skill. No control group was used because of pragmatic reasons involving time constraints.

**Dependent measures.** Memory performance was determined with several outcome variables. Lenient scoring was the total number of words recalled without concern of word order. This was the single variable used to measure general recall performance.

All other variables were used to determine serial recall performance. Strict scoring was the total number of words recalled in exactly the correct position as the original word list. This is the same method of strict scoring used by Roediger (1980). Transpositional recall was how many positions off that the recalled word was from its original position in the word list (e.g., transposition distance, Farrell, Hurlstone, & Lewandowsky, 2013) .

Because transpositional recall turned out to be positively skewed (expanded on in the results section), which created issues for linear regression, two additional measures were added for analysis. *Conditional recall frequency* (CRF) was the total number of word pairs that were recalled in the correct position in the original word list relative to the previous word recalled. That is, if the word “rhubarb” was followed by “vortex” in the original list, and the participant recalled the word pair in this order - as long as the words had no other words in between them - then the participant scored a “1”. CRF measures sequential recall of words, rather than where a word is remembered. Relative CRF was relative to the highest CRF score the participant could have gotten, given the total number of words that they recalled. The relative score allowed for the possibility that the effects of serial ordering could be measured without the implication that higher CRF actually meant more words recalled. Both CRF measures were slightly modified versions of *conditional recall probability* (CRP; Howard & Kahana, 1999). CRP measures serial recall performance of a group of participants, so could not be used to measure individual performance required for linear regression.

**Materials**

**Mnemonic technique instruction.** Participants received a 3- to 5-minute training session in the use of MoL. First, they received oral instructions for MoL, which specified a) imagining an environment, b) imagining items to be remembered, and c) traveling through the environment in order to recall the items (see Appendix A). Then, the experimenter went over up to three examples in detail and answered any questions the participant had. More examples would have made the experiment take too long, although no participant requested more than two. The instructions included the practical uses of mnemonic techniques, in hopes to increase participant motivation to do well with their training.

**Stimuli.** I used 20 words so that I could analyze serial order effects thoroughly. Many studies, particularly Roediger (1980), use 20 words, and show serial order effects. Studies that find weak or no serial order affects (e.g., Legge et al., 2012) use 10 words or less. Fifteen pairs of words were used by Kroneisen and Makerud (2017), but they did not analyze serial order, and as pairs, stimuli may have been treated as single words. As such, 20 words was an appropriate list length for obtaining the necessary variety in performance for looking at predictor variables that could explain differences in recall frequency. I selected the words randomly from a study by Schock, Cortese, & Khanna (2012). The selected words were those rated between 3 and 4 out of 7 for imageability (lower numbers were lower imageability) so that none were especially more imageable than another (see Appendix B).

**Imagery skill tests**. I determined OI with participant performance on a fragmented pictures test (Blazhenkova, 2016). The test was developed from a set of stimuli created for object segmentation and identification (De Winter & Wagemans, 2004). I determined SI with a mental rotation test (Vandenberg & Kuse, 1978; redrawn by Peters et al., 1995; reliability evaluated by Caissie, Vigneau, & Bors, 2009). Both were used to test the validity of the OSIQ and VOSI (Blajenkova et al., 2006; Blazhenkova, 2016). These were the easiest tests to acquire and have strong correlations with their respective OI and SI constructs on the OSIQ. The tests used for each construct respectively had similar scoring schemes in that a correct trial granted one point. For further psychometric details of these tests from previous research, see Table 1.

Table 1.

*Psychometric properties of object and spatial imagery skill tests.*

| Test name | Mean | SD | Maximum | Duration (minutes) | Cronbach α |
|---|---|---|---|---|---|
| Fragmented Pictures | - | - | 34 | 5 | .77 |
| Mental Rotation | 11.5 | 6.1 | 2 x 12 | 2 x 5 | .91 |

**Procedure**

Participants were in a room with a computer. First, the experimenter entered the room and gave the participant training. Then participants were left alone in the room to begin the recall phase. The computer displayed each word to be remembered. Each time a word was displayed, participants were given 15 seconds to encode the item into their memory palace. The word remained on the screen for the entire duration. This duration was to ensure that participants had sufficient time to imagine each item at a locus (e.g., Campos et al., 2009). Any longer and I would have been concerned that participants would find themselves using additional mnemonic techniques, which would make the results harder to interpret. When these 15 seconds elapsed, the next word was displayed.

Once all the words were displayed, participants performed a series of three-digit subtraction problems on paper for 3 minutes. This distraction phase was to induce a retention interval and to prevent any effects of participants rehearsing their memories or using other mnemonic techniques. These problems were used because they were trivial to compute but were time-consuming enough to require attention. Thus, participants would have been unlikely to make use of alternative spatial strategies or refresh information that they used to create their memory palaces.

Following these set of problems, participants began the recall phase. They were told to write down on a piece of paper - in order, starting at whatever word they wanted - the items that they were told to remember. The piece of paper was already numbered, with blanks, from 1 to 20. Where applicable, participants also noted what environment they used as their memory palace. They had up to 8 minutes to work, but they could indicate when they were finished (e.g., Nairne et al., 2007). Lastly, they completed 34 trials of the fragmented pictures test, followed by 24 trials of the mental rotation test. Before each test, the experimenter entered the room to give instructions. Both tests were taken on a computer, with each trial displayed in random order on the screen. The experiment took approximately 45 minutes.

## Results

### Missing data

The measurements of serial recall for three participants were removed from analysis because they were provided with incorrect sheets for writing down recalled words. The mental rotation scores of eight participants were removed from analysis because they consecutively provided the identical answer for more than half of the questions, or because they responded in less than 1 second for more than half of the questions. The fragmented picture score of one participant was removed because they did not receive the test due to a procedural error.

### Descriptive statistics

The majority of the measurements did not have particularly surprising results (see Table 2). Participants remembered a little more than half of words from the word list on average. Strict and CRF scoring were about half of this. Relative to the total number of word pairs a participant could have remembered in order, participants remembered 60% of word pairs in order. Because of this, it did not appear that serial recall of words was constrained by how many words were remembered. This supports the idea that serial recall could be measured separately from recall in general, which was necessary to measure organization separately from retrieval. The original transpositional score - which was simply the total displacement of all words on the word list - did not consider the displacement scores that could be due to chance. The transpositional score was therefore normalized by taking each word recalled by the participant and dividing it by the highest possible displacement score in that position.

Also of note is that the SI descriptive statistics were lower than the expected mean and standard deviation. OI was a relatively stable and likely normally distributed.

Table 2.

*Performance on tasks.*

| Measurements | *M* | Median | *SD* |
|---|---|---|---|
| General Scores | | | |
| Lenient | 11.9 | 12.0 | 4.0 |
| Serial Scores | | | |
| Strict | 5.8 | 5.0 | 4.1 |
| CRF +1 | 6.38 | 6.0 | 4.36 |
| Relative CRF | 0.55 | 0.60 | 0.27 |
| Transpositional | 1.441 | 1.057 | 1.33 |
| Imagery Skills | | | |
| OI | 25.9 | 26.0 | 3.0 |
| SI | 10.1 | 8.5 | 5.9 |

**Recall frequency**

For the entire group, using lenient scoring, recall frequency steadily declined for each word position. With a similar method using strict scoring, recall frequency rapidly declined for each word position until about position 13, where recall flattened out (see Figure 1). This pattern is expected of serial recall, that is, when recalling words in order, there should be a gradual decline in recall frequency.

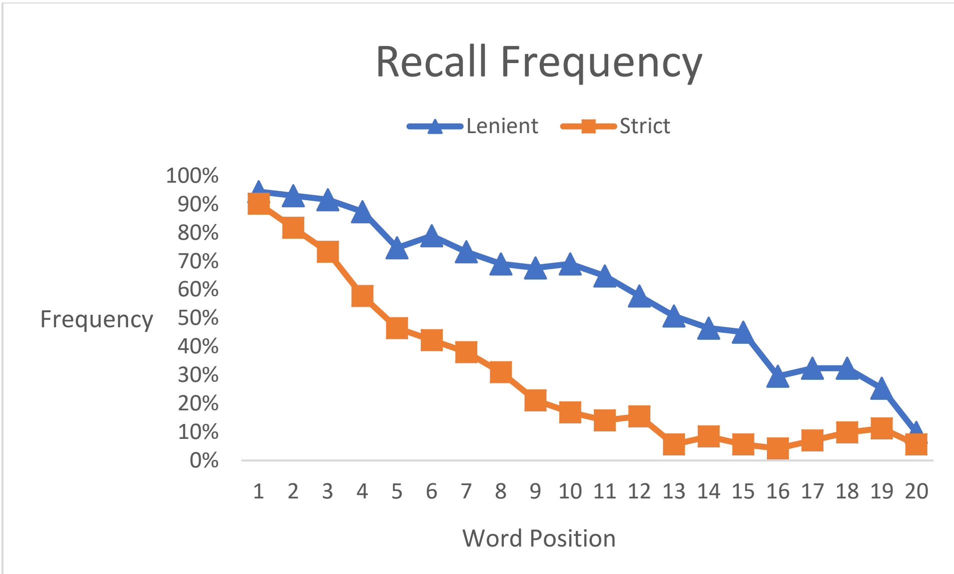


*Figure 1.* Recall frequency by lenient and strict scoring.

**Correlations and distributions**

Correlations among all variables were calculated. The correlations of interest were only those with imagery skills. The distributions for lenient scoring and OI were most likely normally distributed (see Figure 2). Serial scores were not as clear in terms of normality, particularly transpositional score. Formal normality tests revealed that transpositional score was most likely not normally distributed (Shapiro-Wilks $W = 0.825$, $p < .001$).

Nearly all correlations between the variables had a medium effect size (Cohen, 2013), except for relative CRF with OI, whose correlation was small (see top half of Figure 3). Because the transpositional score was not likely normally distributed, a nonparametric test was used, which determined that the correlations of transpositional scores with OI (Kendall's $\tau = -0.03$) and SI ($\tau = -0.082$) were small and not statistically significant. Unadjusted alpha level was set to the standard 0.05. Considering that nine experimentally relevant correlations were compared simultaneously, and transpositional score was left out, adjusted alpha level was determined to be 0.0056 with a Bonferroni correction.

Lenient, strict, and CRF measurements all had similar correlations with OI and SI ($r$ = .33 - .40; see top half of Figure 3). Only OI had statistically significant correlations with lenient and strict scores, while only SI had statistically significant correlations with both CRF scores. This means that both imagery skills displayed some independence. Given the recall frequency results and earlier review, these were not spurious correlations; a visual mnemonic like MoL has some type of relationship with imagery in general, even though imagery skill research has often been inconclusive as a whole. The implication was that OI and SI were reasonably expected to have an relationship to memory performance with MoL, and the results were consistent with this, although temporal precedence and internal validity would still be required to demonstrate causality.. However, the medium effect sizes with both imagery skills across most of the variables suggested the possibility that they are equally modulated by another construct which may be driving the correlations. Since OI and SI had a medium effect size correlation with each other, there was some degree of dependence between both variables. Such dependence could be problematic for performing linear regression and demonstrating any independence between OI and SI when using MoL. The correlation also contradicts evidence that OI and SI are negatively correlated (Blajenkova et al., 2006).

The correlation between OI and SI was not so high that there was evidence that they were actually the same construct - formal tests of multicollinearity confirmed this (VIF = 1.42). Since OI and SI were developed through the idea that imagery skill is insufficient as a construct, their distinction is important. Additionally, relative CRF did not have a statistically significant correlation with OI, but there was a statistically significant correlation with SI and a medium effect size. This is some evidence that certain kinds of imagery skill are more associated with different types of memory performance, i.e., SI compared to OI is more associated with how words are organized for retrieval.

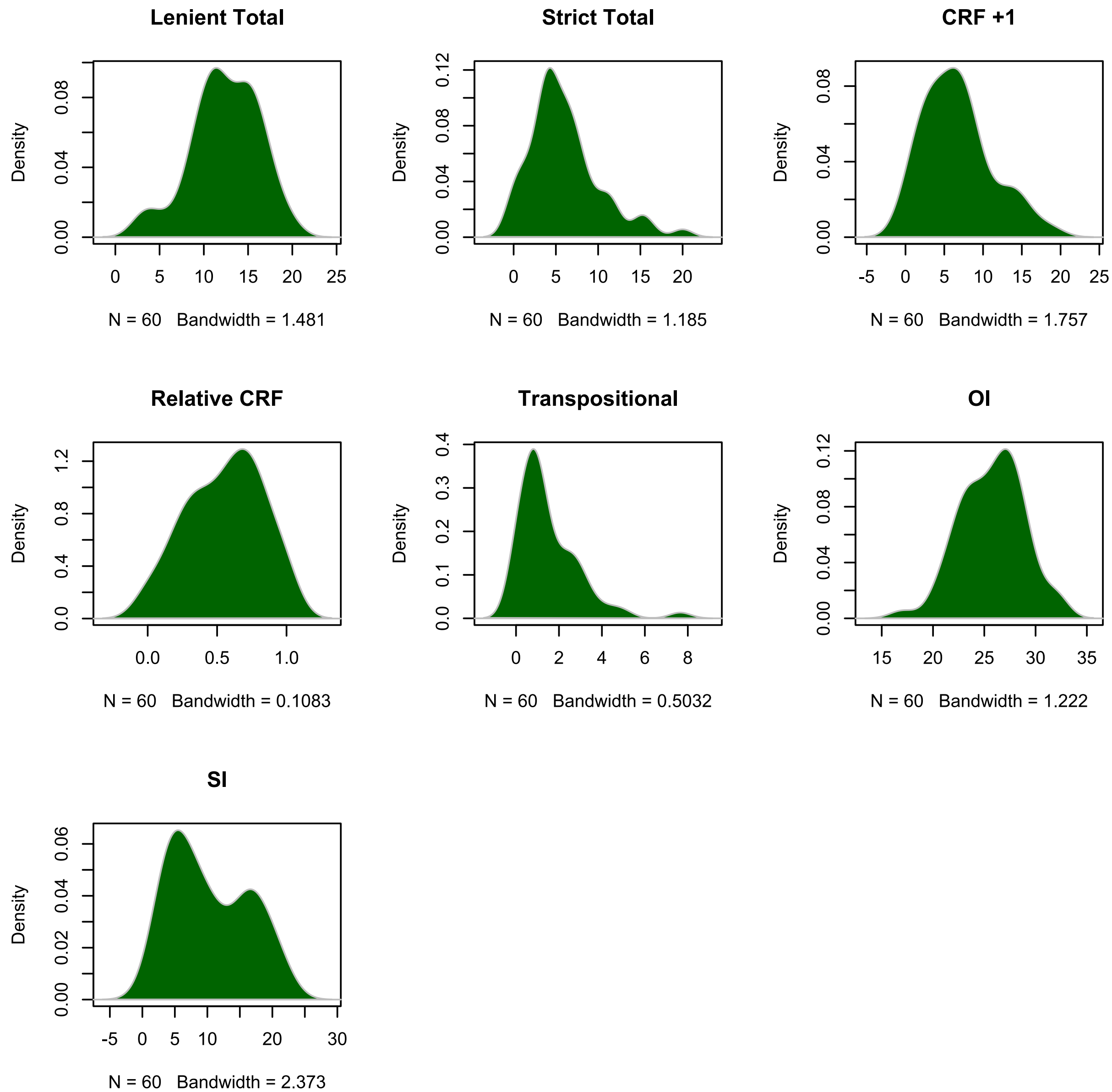


*Figure 2.* Density plots of the variables.

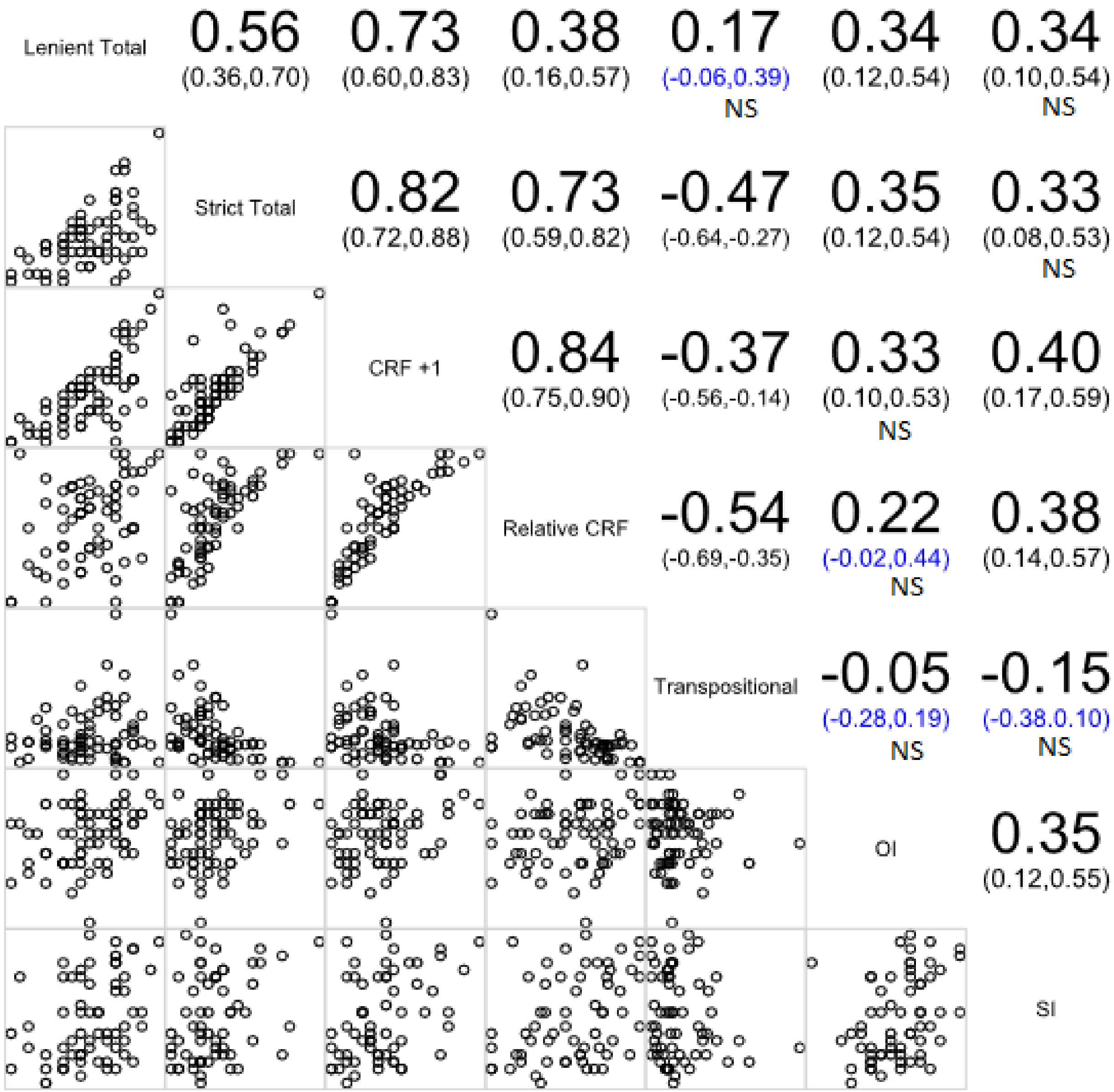


*Figure 3.* Corrgram of all predicted and outcome variables. The diagonal through the middle shows the name of the variables. On the top right are the correlations among the variables, with 95% confidence intervals underneath them. On the bottom left are the scatterplots of the variables. "NS" indicates that the correlation was not statistically significant ($p > .0056$)

**Linear regressions**

Multiple linear regression with OI and SI as predictors was performed. Each memory performance measure (lenient, strict, CRF, and relative CRF) was used as an outcome variable for separate models. Transpositional score was not used as an outcome variable because it violated assumptions of normality. OI and SI were not multicollinear (VIF = 1.42). The strength of all models was small, especially for relative CRF (see Table 3).

Unadjusted alpha level was set to the standard 0.05. Considering that four regression models with two predictors each were compared simultaneously, adjusted alpha level was determined to be 0.0125 with a Bonferroni correction. The multiple linear regression evidence that both imagery skills were independent to some degree, as the impact of different imagery skills were statistically significant for different outcome variables while following different patterns. That is, OI was statistically significant in the lenient model, while SI was not. Beta scores on the lenient and strict models were higher for OI than SI. Beta scores on the CRF and relative CRF models were higher for SI than OI. In these ways, the two constructs were not identical.

To see if removing an imagery skill from the models would increase or keep predictive power, simple regression was done, with the same adjusted alpha levels. The multiple linear regression models were all better models than the models using only OI (see Table 4) or only SI (see Table 5). The fact that combining OI and SI always made for a better model than the simple linear regression models supports the notion that memory performance with MoL was best explained with OI and SI. Additionally, both constructs seemed to play some role that the other did not because OI was significant within the lenient and strict models, while SI was significant within the CRF models and the lenient model.

Table 3.

*Multiple linear regression models.*

| | $R^2$ | *B* | *SE: B* | β | *CI: B* | *p* |
|---|---|---|---|---|---|---|
| Lenient | .196 | | | | | |
| OI | | 0.407 | 0.16 | 0.33 | 0.097, 0.72 | .011 |
| SI | | 0.136 | 0.081 | 0.21 | -0.027, 0.030 | .10 |
| Strict | .166 | | | | | |
| OI | | 0.380 | 0.17 | 0.28 | 0.031, 0.73 | .034 |
| SI | | 0.147 | 0.090 | 0.21 | -0.033, 0.33 | .11 |
| CRF +1 | .204 | | | | | |
| OI | | 0.361 | 0.18 | 0.25 | -0.003, 0.72 | .052 |
| SI | | 0.220 | 0.093 | 0.30 | 0.033, .0.41 | .022 |
| Relative CRF | .137 | | | | | |
| OI | | 0.010 | 0.012 | 0.12 | -0.013, 0.034 | .37 |
| SI | | 0.014 | 0.006 | 0.31 | 0.002, 0.026 | .021 |

Table 4.

*Simple linear regression with OI.*

| | $R^2$ | *B* | *SE: B* | β | *CI: B* | *p* |
|---|---|---|---|---|---|---|
| Lenient | .118 | | | | | |
| OI | | 0.454 | 0.15 | 0.34 | 0.15, 0.76 | .004 |
| Strict | .123 | | | | | |
| OI | | 0.472 | 0.16 | 0.35 | 0.16, 0.78 | .004 |
| CRF +1 | .108 | | | | | |
| OI | | 0.470 | 0.17 | 0.33 | 0.14, .0.81 | .022 |
| Relative CRF | .049 | | | | | |
| OI | | 0.020 | 0.11 | 0.22 | -0.002, 0.041 | .072 |

Table 5.

*Simple linear regression with SI.*

| | $R^2$ | *B* | *SE: B* | β | *CI: B* | *p* |
|---|---|---|---|---|---|---|
| Lenient | .115 | | | | | |
| SI | | 0.223 | 0.079 | 0.34 | 0.066, 0.38 | .006 |
| Strict | .107 | | | | | |
| SI | | 0.227 | 0.085 | 0.33 | 0.056, 0.40 | .010 |
| CRF +1 | .163 | | | | | |
| SI | | 0.301 | 0.089 | 0.40 | 0.12, .0.48 | .001 |
| Relative CRF | .142 | | | | | |
| SI | | 0.018 | 0.006 | 0.38 | 0.006, 0.029 | .003 |

## Discussion

This study was designed in order to investigate the effect of OI and SI in the context of memory performance using MoL. Ability to visualize individual objects was hypothesized to be associated with word recall. This was tested in terms of how OI predicted recall frequency of words on a list. Ability to visualize spatial relationships was hypothesized to be associated with how words are organized for recall. This was tested in terms of how SI predicted serial recall of words. The results demonstrated that, based on linear regression, OI predicted (and had significant correlations with) strict and lenient scores to a greater degree than SI, and that SI predicted (and had significant correlations with) both CRF scores to a greater degree than OI. Both imagery skills were associated with distinct patterns in that they were statistically significant in different regression models and in different correlations. However, nearly all scores had a medium effect size correlation with OI and SI. The regression models were not particularly strong either. Therefore, there is not enough evidence to conclude that OI and SI are functionally distinct or nearly as separable as hypothesized.

One may question whether participants really did use MoL. But the pattern of recall frequency at the group level was that expected when MoL is used. In particular, there were primacy effects, even in terms of strict recall. The first two words were recalled in perfect order with very high frequency ( > 80%). There was a low frequency ( < 10%) that the final word was recalled in perfect order, which is lack of a recency effect. MoL is about traversing space with an explicit beginning and encoding information from the beginning, so if one uses MoL, primacy effects are expected. The strict recall frequency curve gradually declined rather than rapidly, suggesting that ordering was being preserved. If a control group were used, further evidence could be a less steep serial recall frequency curve compared to a control group. Additionally, all participants reported using a memory palace. Altogether, short of a thorough interview, there is some reason to believe that most or all participants used MoL.

Generally, OI appeared to be associated with the clarity of imagined objects, and placing those objects in their proper locations within a memory palace. This might also mean that loci are visualized as objects, or even that objects become loci. The words on the list were not especially high on imageability, so skill mattered that much more. Greater clarity of images may therefore be responsible for the high degree of retrieval when one uses MoL.

Both CRF scores were predicted by SI to a greater degree than OI. The way a participant organizes information appeared to have something to do with manipulating spatial environments in imagination, or the spatial relationships between items in the memory palace. Objects are not rotated when retrieving items from a memory palace, so it may be difficult to draw theoretical conclusions when SI was measured through mental rotation. But clusters of objects in proper organization may require changing one's point of view within imagination. Rotating one's view would be the same as orienting towards the position of the next object in the memory palace. Proper orientation would assist with successful recall of the next position. This process of spatial manipulation may therefore be responsible for the high quality of organization when one uses MoL

**Taxonomic and theoretical considerations**

Splitting up imagery skill into two separate constructs resulted in two distinct association patterns when used in regression models. But because of the strength of all the correlations (especially between OI and SI), scientifically precise explanations cannot be offered for the mechanisms of MoL. Both general observations seem to conflict with each other. Fortunately, the two distinct association patterns leave room for describing observations related to memory.

In other words, there is enough information to begin a taxonomy of mnemonic devices and a classification scheme with their various descriptive characteristics. A taxonomy is intended to organize information categorically and descriptively in a hierarchical manner, without any specific theory in mind (Glushko, 2013; Willingham & Goedert, 2001). Given the observed distinctions, it is fair to say that OI and SI are descriptive characteristics of MoL. They provide a more precise way to describe MoL than “visual mnemonic technique”. The means of visualizing for the sake of MoL can be described through the data as including visualizing spatial and object elements.

Taxonomies are not created as theories. Yet this does not mean that taxonomies are not scientific. Bellezza (1981) already offered something of a taxonomy by pointing out the organizational and retrieval characteristics of mnemonic devices. This conceptual framework was intended to show a path towards analyzing mnemonic techniques. This is what I have done with MoL by further describing it - and by observing the technique in action. With classification comes clearer ways of thinking or inspiration for theory (Willingham & Goedert, 2001). Taxonomies describe what a theory should account for. However, care must be taken to remember that development of a taxonomy for mnemonic devices is not the development of a memory theory, proposal of memory systems, or dissociation of memory processes.

Including OI and SI as attributes of MoL immediately implies the broader category “skill”. These imagery skills are active by virtue of being skills, or else they would not properly be described as skills. For instance, in imagery skill tests like mental rotation, deliberate effort is required. They are not necessarily memory skills per se but they did predict memory performance to some degree, so there is some active process when using MoL, and by extension, episodic memory would at least sometimes involve active processes. Descriptively speaking, there is more going on with MoL retrieval than a memory trace of simply finding a complete memory (cf. Michaelian, 2016).

If I am to include skills as part of MoL, such that there is some active procedure for placing items in a memory palace (i.e., encoding), then it makes sense to describe some active procedure for taking items out of a memory palace (i.e., retrieval). Active retrieval might not necessarily be only re-creating the conditions in imagination during encoding. Much emphasis has been placed on the encoding procedures of MoL, but not so much about retrieval procedures.

Mnemonic devices like MoL do not by nature determine retrieval strategies that participants must use. True, MoL users imagine themselves following a path, perhaps with the implication that cues are present. But past this, the user can do whatever they want. They could reach out and grab an item, they could smell the item, they could take the item apart. Whether or not different techniques could make a difference, it does not matter. The point is that a full description of MoL require some classification of retrieval procedures if one wants to avoid ad hoc additions.

One way to describe a retrieval procedure for MoL is creative use of imagery. Since there was no rigorous procedure for how to use imagery during retrieval (as opposed to the numerous precise recommendations since antiquity of how to construct a memory palace), it is up to the user to determine how a retrieval problem should be solved. There are many options available for a user, even between users who can visualize images equally well. A taxonomy of mnemonic devices would do well if these considerations can be organized.

For theoretical advancement, more research must be done, including different procedures to examine serial recall, or examining the imageability of environments. But constructing a scientific hypothesis about MoL has been made easier by noting additional descriptive characteristics. For imagery in particular, the results allow for the further development of hypotheses about imagery and MoL. I have formed two hypotheses, post hoc, from my descriptive observations.

The first hypothesis I refer to as the *memory imagery specialization* hypothesis. The idea is that different visual mnemonic techniques specialize in harnessing different imagery abilities. MoL is made up of spatial and object characteristics, and these characteristics would receive dedicated methods of processing object and spatial information. Although they would be somewhat dependent in the sense that they affect each other, the processes would operate distinctly as well. This idea is based on how OI and SI different association patterns in my experiment. Imagery specialization by mnemonic devices makes sense in light of how using MoL results in higher reaction time compared to SP, and even compared to visual imagery in general. If visual imagery only taps into OI, but MoL taps into both SI and OI, then MoL should take longer for no reason other than more imagining is required. Such an explanation of why SP and visual imagery are different than MoL could not be offered in the original study by Kroneisen and Makerud (2017).

Such a hypothesis has precedent in memory research that deals with visualization in a theory called the *dual coding theory* (Paivio, 1991, 2010, for reviews). This theory proposes that cognition involves two functionally distinct yet interconnected systems: logogens (largely verbal units like words or sentences) and imagens (largely nonverbal representations that bring about imagery). In terms of memory, when encoding a word such as “dog”, according to dual coding theory, both the word (logogen) and the image of the dog (imagen) are stored. Maintaining both codes allows for stronger memory than otherwise. My hypothesis is parallel to this theory in the sense that two different processes are used to deal with the same information (words on a list).

Both skills can be used for mnemonic techniques, and when both are used, they reinforce each other, just like dual codes would. MoL might work so well compared to any other mnemonic technique because both skills are required. There is evidence of this with the medium correlation between OI and SI. Under this hypothesis, they would have a simultaneous causal impact on retrieval.

A second hypothesis is based on the spatial scaffold theory (Robin, 2018). The idea is that SI has a general benefit across all mnemonic techniques, especially and including MoL. If spatial characteristics underlie episodic memory, then even if a specific technique does not use spatial characteristics, the mental representations of the items to be remembered or relevant information are affected by SI. This is not to say that SI itself improves retrieval mechanisms, but this does mean that SI is a pre-requirement of effective retrieval. If encoding is done effectively, then recall should be proportionally effectively. After all, effective encoding necessarily implies effective organization, so retrieval processes would be less affected by phenomena like interference where words might be remembered in the incorrect list. This is the foundation of mnemonic techniques. However, the causal chain here is different than the memory imagery specialization hypothesis: SI causally affects encoding; encoding causally affects retrieval; OI causally affects retrieval. Encoding and retrieval are bound tightly together (which explains why OI and SI would have a medium correlation), so it is difficult to tease apart what affects encoding and what affects retrieval. This hypothesis would say MoL works so well because it specifically takes advantage of the spatial scaffold, rather than simply because imagery is helpful.

One should recall how people spontaneously add spatial context to episodic memories, which was already some reason to think that SI is a distinct kind of imagining; objects and people would not be added spontaneously (Robin et al., 2016). MoL offers guided use of SI, so if SI can be functionally distinguished from OI, MoL is in a unique position to promote the use of the spatial scaffold. This line of reasoning offers a narrow reason why a highly specific method like MoL works so consistently well compared to other mnemonic techniques. Narrowness also means that the same reasoning could not apply to other techniques - if the reasoning applied to other techniques, then explaining why MoL specifically works so well would be much more difficult.

**Limitations**

I investigated the effects of MoL, not simply the natural (untrained and unguided) factors of encoding and retrieval. This makes it so that limitations of the study are not so difficult to detect because they will often be related to the experimental procedure. Participants were told how to use their memory, which makes for a relatively closed environment.

One general limitation was the lack of anything in the procedure to examine the quality and characteristics of a memory palace. An environment is not necessarily continuous in imagination. There may very well be gaps in the memory palace. There was no measure of the quality of the memory palace, and there was no prior reason to expect that OI would have to do with imagining environments. Memory palaces may also differ in shape. Procedures involving virtual reality may help control these type of limitations (Legge et al., 2012).

Another procedural issue was that participants were only given at most 5 minutes of training on using MoL. If more training were given, as was the case in several studies (e.g. Cornoldi & De Beni, 1991; De Beni & Cornoldi, 1985; Massen, Vaterrodt-Plünnecke, Krings, & Hilbig, 2009), then participants might have better realized the potential of MoL or shown a different pattern of results.

The serial recall scores posed another limitation. They might not have been the best representation of the spatial organization used for MoL. It was an assumption of the experiment that the spatial organization was a sequential and linear ordering. The ordering of any word list is sequential and linear. Traveling an imagined path is of course sequential, but it is not necessarily linear. Some environments are (imagine a long office building with no turns and a linear ordering of rooms), while others are not (imagine a museum where there are many different paths to the same exhibit).

The way I operationalizationed OI and SI was also potentially an issue. There may be more robust ways to measure one's OI. The validity of both imagery skills was determined through a battery of tests, not a single test. The Fragmented Pictures Test was the best individual test in terms of correlation with OI, but that does not mean it is necessarily sufficient for an accurate measure of OI. On top of this, MoL might not even take advantage of image completion skills required of the test. That is, whatever skill used to visualize items in MoL might be a mediating variable that in turn correlates with the skill used in the Fragmented Pictures Test. The same form of argument could be applied to the Mental Rotation Test. Since the results pertaining to CRF scores and SI were weaker than the results pertaining to lenient scores, strict scores, and OI, the argument is even stronger for mental rotation. On top of this - even though mental rotation is a spatial imagery skill - in terms of MoL, it might only be necessary for rotating or manipulating objects within a memory palace. A better operationalization (and stronger results) could involve imagining or visualizing environments for the purposes of navigation. This could better correspond to the spatial features of MoL.

## Conclusion

If the ancient Romans and medieval scholastics were right about their art of memory (mapping information to be remembered onto mnemonic objects), then episodic memory can be enhanced through deliberate effort and strategies (Vergara, 2012). And if it can be deliberately altered through different techniques, then there is no reason to think that encoding or retrieval is a passive process. Instead, there would be good reason to think that episodic memory is active and participatory. The results of my experiment fit this perspective: imagery skill can affect how well one remembers.

More research is required to say if SI and OI our independent constructs. If they are, further experiments are needed to disentangle what might be a spatial scaffold at work, or a phenomenon unique to applying visual mnemonic techniques like MoL. And even if neither is the case, constructing a taxonomy of mnemonic techniques will help make better sense of what questions to ask to figure out why MoL works so well. Yes, (Roediger, 1980) especially showed that MoL works well, but he did not show why. In fact, a number of studies have seemed to only test out MoL in different scenarios rather than its mechanisms (Legge et al., 2012; Massen & Vaterrodt-Plünnecke, 2006). Understanding the truth underlying the matter would provide insights into the nature of mental imagery, and in just what way one's ability to imagine affects the very way they remember their world and their experiences.

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**Appendix A - Method of Loci Training**

I'm going to train you how to use the method of loci. The method of loci is a technique used to remember a lot of things. It's been around for a long time, used by the ancient Greeks and Romans. Many people use it to remember huge amount of information, and plenty of students use it to study. Since you're a student yourself, there's a lot of use you will find from learning how to use it. With your help, I'll find out ways to make it work even better. That's part of what my experiment is for. I'll tell you more details about the method at the end.

Basically, it involves mental images and places. First, you picture an environment. Any type of place you can imagine. Then, you picture the things you want to remember. Perhaps those things are items in a shopping list, or lines of a poem. It doesn't matter what the things to remember are, as long as each thing is pictured as a single image. The image can be as strange or as normal as you want. Next, you imagine placing those things into the environment. It's best when the image and the place interact, such as hanging a giant clock on the wall. What you've created is called a memory palace. Lastly, you imagine moving through the environment on your own. Whenever you want to remember the items, just imagine moving through the environment. When you do this, you will end up remembering everything in pretty good order. This might sound like a lot of steps to just remember things, so we will go over a few examples before moving on to a hard example.

The environment we will use is your home.

We're going to use this list of words. Create a mental image of each word as you read. As you read each one, also place them somewhere in your house, in order of how you might pass them if you walk through your house. You might know other ways to remember these words, but please stick to the method of loci.

Apple

Happy

Peanut

Biology

Opera

Now, imagine yourself walking through your house. Remember all the things you placed in the house and say them out loud. I'll tell you if you're right.

Do you have any questions? We can go over one more example if you want to.

[Answer any questions as necessary. If they want to go over another example, let the participant pick their own environment. Use the following words: book, sad, lamb, knowledge, train.]

We'll move onto the hard trial in a little while! For now, think of a familiar environment to use for your next memory palace. Please use a different one than one we've practiced with. You will be using this environment later in the experiment.

[Begin the experiment phase.]

Based on (Kroneisen & Makerud, 2017; Legge et al., 2012; Roediger, 1980)

## Appendix B

The following 20 words in random order were used during the encoding phase of the experiment.

answer
beret
cello
drowsy
epic
finance
frigid
garnish
justice
language
middle
noble
opal
physics
rhubarb
surprise
talon
vortex
worry
yodel