A VIRTUAL MEMORY PALACE AND THE USER'S AWARENESS OF THE METHOD OF LOCI

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Research paper

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Abstract

The Method of Loci is an ancient Greek mnemonic strategy used to improve memory performance by associating to-be-remembered items with familiar places (loci) in an environment. In order to see the possibility to reduce the extra mental effort needed for using this mnemonic, this study tests the recall performance after participants' mere exposure to a visuospatial virtual memory palace (VMP). More precisely, we aim to investigate whether it is necessary to introduce or educate this method to users before they enter a VMP. Our results demonstrated that even without conscious awareness of the application, or even the existence of the MOL, the memory performance is not attenuated. Thus, the application of such VMP in an educational context can be simplified.

Keywords: e-learning, Method of Loci, Virtual Memory Palace, Conscious Awareness.
1 Introduction

The Method of Loci (MOL) is one of the oldest and most effective mnemonics. According to Yates (1966), a list of to-be-remembered objects can be later retrieved by firstly associating them with familiar places (loci, singular = locus) inside an environment, then mentally travelling through this environment and picking up the objects in order (Yates, 1999). A memory palace is basically the advanced strategy of the MOL. All the items that a user wants to memorize are mentally stored in a familiar environment at certain loci. If the user wants to recall the items, s/he traverses the memory palace mentally.

Several controlled lab studies demonstrated the effectiveness of this method in a variety of content areas for learners aging from children to adults (Brehmer et al., 2007). Nowadays, the MOL is mostly applied in rote memorization tasks, e.g. words-list recall (McCabe, 2015). Another typical application would be language and vocabulary learning using gamification and MOL (Rawendy et al., 2017). Although teachers aspire for their students to be “critical, insightful, curious, and deeply appreciative of the subject matter” (Bower and Reitman, 1972), higher education still requires a remarkable amount of fact learning, which the MOL can help with. Bloom and Lamkin (2006) showed the effectiveness of mnemonic for undergraduates to remember the Cranial Nerves. Qureshi et al. (2013) suggest that the MOL is an effective technique in learning physiology that can also be used in other disciplines related to medicine. Shaughnessy and White (2012) described how to adapt the MOL in the economics classroom for the purpose of memorizing large amounts of information in economics. All of them suggest a great potential for this method to be also applied in higher education for students to retain a larger amount of new concepts and information.

In 2015 Putnam evaluated the use and integration of mnemonics in combination with other learning strategies. Despite the great potential of the applicability of MOL, mnemonic strategies were still not fully implemented in the teaching community (Putnam, 2015). This may be due to the extra mental effort that is needed to create the loci. In order to lower the cognitive loads while applying the MOL and to ease the burden of learners, researchers in the field of computer science and psychology started to introduce the virtual world to the application of this mnemonic. The integration of virtual memory palaces (VMP) supports the traditional mental representation of the memory palace. Instead of a familiar environment, the VMP serves as a template for the mental representation of the memory palace. VMPs illustrate a promising way for the application of the MOL in an e-learning context, by offering the feeling of presence and higher immersion.

However, with the help of a VMP, users still have to be trained or informed of the mnemonic before they enter the VMP and apply this method; that is why a further improvement of MOL would be necessary to minimize the mental effort of users. Previous lab studies were mostly conducted under the condition that participants were already informed about the MOL (Roediger, 1980; Brehmer et al., 2007; Ng et al., 2010; Legge et al., 2012; McCabe, 2015; Jund et al., 2016; Huttner and Robra-Bissantz, 2017; Dresler et al., 2017; Huttner et al., 2018). If a mere exposure to visuospatial VMP also helps with memorization, it will not be necessary for teachers or professors to spend a large amount of time explaining what MOL is and training their students. This could be relevant not only for adult learners but also in classroom settings with younger learners as in elementary schools, for whom being educated about this method would be a demanding task. Also, as self-directed-learning becomes a mainstream in an E-Learning context (Song and Hill, 2007), saving the step to be introduced about mnemonics can improve the learning efficiency significantly. At the same time, it offers great opportunities for e-learning application designers to apply this method without concerning about users’ pre-knowledge.

This study focuses on the influence of conscious awareness of the existence of the MOL on the recall ability. More precisely, we tested participants’ recall performance of a list of words when they were not consciously aware that those words were being presented in the way of the MOL. So the learning process (in this case the memorization process) should occur incidentally. By comparing the recall
performance of these participants with those who were informed about the MOL before the experiment, we aimed to investigate if the introduction of the MOL is crucial to successfully use a VMP.

2 Related Work

This study is based on two strains of research, basic research of the MOL especially in an educational context and research related to cognitive function of the MOL.

Besides the application of this method in physiology and economic classroom settings as mentioned in the introduction part (Bloom and Lamkin, 2006; Shaughnessy and White, 2012; Qureshi et al., 2014), Hartwig and Dunlosky (2012) as well as McCabe (2011) also suggested that mnemonic strategies should be integrated into students’ curriculum as they may improve students’ performance in universities. Moreover, Putnam (2015) pointed out that students would have more time coping with higher order learning. Here, mnemonic strategies may help to master the first level of learning, which is “remember” according to Bloom’s taxonomy. It classifies educational learning content into levels of complexity and specificity (Krathwohl, 2002).

However, students tend not to use mnemonics, despite the fact that they already know mnemonics such as the MOL (Putnam, 2015). McCabe (2015) indicated that the mental effort necessary to establish a working mnemonic may explain why. An important limitation of the MOL is that the use of this mnemonic in a traditional way requires extensive training, e.g. two 1-hour training sessions according to Brehmer et al. (2007), three 40-minute training sessions according to Bower and Reitman (1972), 4-6 hours of training with older adults according to Brooks, Friedman Gibson and Yesavage (1993), two training and six adaptive practice sessions, each lasting 1-1.5 hour, prior to testing, according to Kliegl, Smith and Baltes (1989), one session of training and asked to practice overnight and the next day prior to testing according to Roediger (1980).

The influence of the familiarity with the loci and the MOL on memory performance was considered by studies related to the cognitive function of the MOL. According to Legge (2012), using an unfamiliar virtual environment is not significantly different than using a real and familiar environment for the MOL, while other studies mentioned that familiarity with this method may influence the recall performance (Legge et al., 2012; Putnam, 2015). However, these studies were all conducted to evaluate the effectiveness of the traditional MOL, which requires the participants to create loci and associate objects with unfamiliar loci by themselves. As the introduction of a VMP alters the traditional protocol, the influence of the familiarity with this method needs to be considered once again. While the traditional MOL protocol asks the user to build the memory palace only mentally, a VMP serves as a visual template. Therefore, the cognitive load and effort which is necessary to successfully apply the MOL changes and opens up new research questions.

Dresler et al. (2017) showed in their study that the brain network organization associated with superior memory can be stimulated by mnemonic training, not just by the mere exposure to the visuospatial principles of the strategy. In this case, they gave an introductory course in the MOL to the participants (Dresler et al., 2017). In contrast, Bellezza and Reddy (1978) conducted an experiment to investigate if the MOL function like natural memory process. They compared the recall performance of participants using familiar loci provided by themselves and unfamiliar loci provide by the experiment designer with a control group. None of the participants was informed about the recall task in the first place, instead they were asked to rate the concreteness of a list words after the session, in which they should firstly imagine the word and then place it in loci (Bellezza and Reddy, 1978). In this study, a similar methodology is adopted and it focuses merely on finding out the influence of conscious awareness of the existence of this method on the participants’ recall performance.
3 Research Approach

This study aims to contribute to further simplify the applying of the MOL in a VMP and to investigate the recall performance after a mere exposure to the visuospatial VMP and without conscious awareness of the MOL. Driven by this intention, the design science methodology based on Hevner (2004) (Hevner et al., 2004) and refined by Peffers (2007) was chosen as an approach to conduct this study. Section one and two outlined the potential lying in the application of the MOL and VMP for an educational purpose, the problem of the extra mental effort and the objectives of this study. In the following sections, the experimental and the prototype design will be introduced. The results of the evaluation and discussion of the findings as well as the conclusion will be covered in the later sections.

In order to investigate the effectiveness of the MOL without the conscious awareness of the application of this method, we conducted an experiment for our study. Participants were divided into three groups. We defined group 1 as the group with conscious awareness of the applying of the MOL in VMP (cMOL = conscious MOL), group 2 as the group without such awareness (uMOL = unconscious MOL) and group 3 as a control group using traditional mental MOL (CON = control). This control group was also asked to use the MOL since the experimental design should allow to compare the traditional versus the virtual MOL. Moreover, several studies already supported the superiority of the MOL over traditional learning strategies.

Obviously, to examine a mere exposure to the visuospatial VMP would also enhance learning performance, participants in group 2 (uMOL) should not be aware that they were learning the list of words that were presented. Otherwise, it would be difficult to control whether some participants, who already had experience with this method, would consciously or subconsciously apply the MOL, if they were informed of a memorization task. Moreover, in order to control the fact that different tasks may result in noticeable difference in recall ability, we gave participants in all three groups a fake task (same in all groups) instead of the real recall task. Later, we will discuss in detail whether the fake task could lead to a general decrease in recall performance. However, as long as all the participants were given the same task, this decrease would be equally occurred in all three groups, which should not interfere with the aim of this study.

As mentioned in section 2, Bellezza and Reddy (1978) conducted their experiment to investigate if the MOL functions like natural memory by making learning incidental. Hence, none of the participants was informed about the real task. Instead, participants were told that the purpose of the experiment was to test their visual imagery and imagination (Bellezza and Reddy, 1978). Modified from their study, all the participants in our study were informed that this experiment aimed to test personal visual imagination. As all the participants were presented with a word and an image, they were told that they should rate the similarity of the images presented to them with their own imagined pictures of these words. They were also told, they should interact with the words and images before they rate the similarity. Participants in Group 1 (cMOL) and 2 (uMOL) should explore the VMP and interact with the words and images firstly. The only difference is that participants in Group 1 were given a brief introduction of the MOL and what a VMP is. But they were told that the experiment is not about memorization but rather the rating task to improve design features in a VMP. Participants in group 3 (CON) were also introduced with the MOL because for interaction with these words and images, they should associate the objects with loci in their own memory palace. In the post-experiment questionnaire, we asked all participants if they had already anticipated the real task during the experiment (dichotomously: yes or no) since this may influence the variance of the participants’ recall performance.

To measure the recall performance, we used two approaches introduced by Legge et al. (2012), the strict score and the lenient score. The strict score reflects the percentage of the correct words in the correct position. A detailed description of how it was calculated will be given in section five. The lenient score measures the overall proportion of words that could be recalled, regardless the correct position. Since the effectiveness of applying the MOL without conscious awareness of the existence of this method yet remains a relatively unexplored area of research, we could not hypothesize any superior performance of a group. Hence, the derived hypotheses are as follows:
**H1:** There will be no statistically significant difference between the conscious MOL group and the unconscious MOL group on the *lenient score.*

**H2:** There will be no statistically significant difference between the conscious MOL group and the unconscious MOL group on the *strict score.*

### 4 Experimental Design

This section gives a description about experimental settings for our study, i.e. the participants and stimuli, prototype and technology, as well as the experimental procedure.

#### 4.1 Participants

A total of 62 participants, aged 21-34 (mean = 25.51, 37 males, 25 females) participated for no financial incentives. 58 of them are university students and 4 of them have already graduated from university. Participants signed-up for the experiment via an online system and were randomly assigned to one of the three groups. Note, participants who are non-native German speakers are all students in a German university attending lessons and exams which are conducted in German. Also, they were equally distributed in three groups. Hence, this factor is not considered as an independent factor having an impact on the result. Two groups conducted the session in a VMP (Group 1: cMOL = conscious MOL, Group 2: uMOL = unconscious MOL) and the third group conducted a traditional mental MOL session serving as a control group (Group 3: CON = control). Three participants (1 male, 2 females) reported severe motion sickness and withdrew from the experiment. Two participants’ recall results were not recorded in the database. Hence, a total of 57 participants provided data for this study (Group 1 cMOL: 23, Group 2 uMOL: 22, Group 3 CON: 12). A control condition without any MOL application was not considered in this study because of two main reasons. First, the statistical power would be even lower due a limited sample size. Second, the benefit of the MOL was shown in many studies as mentioned in earlier sections (Witmer and Singer, 1998; Agarwal and Karahanna, 2000; Mania and Chalmers, 2001; Lin et al., 2002; Sowndararajan et al., 2008; Ragan et al., 2010)[1]. The effect of conscious awareness of the MOL on recall ability would only be meaningful on the premise of the benefit of this mnemonic. Therefore, this study mainly focuses on the effect of the conscious awareness of the MOL (comparison between cMOL and uMOL).

#### 4.2 Stimuli

Bellezza (1981) suggested that a list with less than ten words should be avoided for a MOL investigation, because the effectiveness of the MOL would not be noticeable in that case. Furthermore, Malaga (2000) pointed out that if a picture is named to a subject, certain images may appear in his/her visual mind while reading a particular word. According to the dual coding theory of Paivio and Lambert (1983), a simultaneous presentation of pictorial and lexical stimuli results in an improvement of the retention performance. Also the studies from Fleming (1979), Shepard (1967) and Standing (1973) supported the statement that a superior memorization performance can be achieved with the help of a combination of text and images over either only texts or images being presented. Hence, a list of 40 words was used as stimuli as Ross and Lawrence (1968) suggested and applied in their study. Along with the words, 40 images were presented simultaneously. The concreteness of nouns, i.e. the difficulty level for people to form mental images of the word, could influence the recall performance according to Bellezza and Reddy (1978). Also Legge et al. (2012) pointed out in their study that words with high concreteness are easier to remember in general than those with low concreteness. To lessen the mental effort for participants, words for our study were taken from the list “Leipzig Affective Norms for German (LANG)” (Kanske and Kotz, 2010), in which a list of 1,000 German nouns were rated for emotional valence, arousal, and concreteness. Nouns with top 40 concreteness combined with images were chosen as stimuli for this experiment.
4.3 Prototype and Technology

Jund et al. (2016) suggested that a higher level of immersion should positively influence the virtual MOL experience. Legge et al. (2012) also stated that the use of VR has a positive influence on the users’ intention and ability to apply MOL. Since the aim of this study is to further reduce demanded mental effort for the MOL when entering a VMP in an educational context, the VMP was developed for a head-mounted display (HMD). A HMD generates a higher immersion than a mere application of a regular screen. Participants in group 1 (conscious MOL) and 2 (unconscious MOL) conducted this experiment in a virtual reality environment wearing a HMD with a smartphone as the display. The smartphone screen generates a stereoscopic camera perspective focused by two lenses in the actual HMD. Participants can navigate themselves in the virtual environment by using a Play Station gaming controller. In addition to that, participants conducted this session in a seated position with a rotary chair. This way, participants were able to look around easily and navigate with little effort.

The VMP was designed as a virtual apartment and the loci were covered as a white box with a black question mark on it. Participants were spawned at the entrance of the apartment where the first locus was placed. The loci were not visible or accessible all at once so participants had to uncover them one after another. This way, the VMP design ensured that participants had to follow a predefined walking path in an VMP to find all the loci. The user had to focus on the square and press a controller button to activate the locus (term and image). Each item was presented for five seconds and then disappeared. In order to reveal the next item, the participant had to find it nearby. The objects in the VMP were located quite close to each other and no participant reported difficulties to find them. The time frame of 5000 ms (or 5 seconds) was adopted from the study conducted by Legge et al. (2012). Figure 1 shows an uncovered locus in the VMP (“Brief” means letter) in a stereoscopic camera perspective. Due to this procedure, the inter-stimulus interval was determined by the movement behaviour of each participant.

![Figure 1. Locus in the Virtual Memory Palace](image)

For the control group conducting a traditional mental MOL, words and images were presented with a Macbook Pro with a 13.3-inch screen. Same as for the other groups, each stimulus was presented for five seconds and disappeared afterwards. By pressing a button on the laptop, the next stimulus appeared on the screen, so the conditions resemble the ones in the experimental groups.

4.4 Procedure

Before the experiment started, all the participants were briefed as following, which was modified from the experiment conducted by Bellezza and Reddy (1978).
“This experiment aims to test personal visual imagination. In this session, you will be presented with 40 words with pictures. After the session, you will be asked to rate the similarity of these pictures with your own mental imagined pictures of these words. At the end, we will ask you to fill a questionnaire to give us a feedback of the general experience.”

In addition to the Information above, participants in different groups were given additional information accordingly as mentioned in the previous section. Participants in Group 1 (cMOL) and 2 (uMOL) were asked to explore the VMP and interact with all the words and images. The only difference is that participants in Group 1 were given a brief introduction to the MOL (see Appendix) and were told that the VMP they were going to explore was designed according to the MOL. Participants in group 3 (CON) were also introduced with this method because they had to imagine their own memory palace and associate the objects with the loci. The words and images presented to group 3 were exactly the same as those that were presented to group 1 and 2. Then, a training session was provided for them to get familiar with the navigation technique so that the interaction should not interfere with the real memorization task. After the participants were confident with the navigation and the interaction, the experiment started. Participants conducted their sessions according to their group. Once it was completed, the retention procedure began immediately. At this point subjects were informed about the real task to recall the 40 words in order. Figure 2 illustrated the different phases of the experiment.

<table>
<thead>
<tr>
<th>uMOL</th>
<th>cMOL</th>
<th>CON</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Fake task</td>
<td>Explanation MOL &amp; fake task</td>
<td>Explanation MOL &amp; fake task</td>
</tr>
<tr>
<td>2 Passing the training level</td>
<td>Passing the training level</td>
<td>Presentation: words and images</td>
</tr>
<tr>
<td>3 Memorization in the VMP</td>
<td>Memorization in the VMP</td>
<td>Recall phase</td>
</tr>
<tr>
<td>4 Recall phase</td>
<td>Recall phase</td>
<td>Recall phase</td>
</tr>
<tr>
<td>5 Questionnaire</td>
<td>Questionnaire</td>
<td>Questionnaire</td>
</tr>
</tbody>
</table>

Figure 2. The five phases of the experiment.

The recall task was conducted on a web interface which was developed to save the subjects’ input in a database. This blank page with a single text field and two buttons (one for input confirmation and one for skip) was also developed according to the one Legge et al. (2012) used for their study. The time limitation of the recall task was set to 10 minutes. When the recall task was completed, all of the subjects were asked to fill a questionnaire about their gender, age, educational level as well as other feedbacks of this session. Also, they were asked about whether they had pointed out the true intention of this experiment.

5 Results

As mentioned earlier, the recall performance was operationalised as the lenient and strict scores. Calculating the lenient score is quite simple as it is only the amount of correct words that could be recalled. The strict score also includes the position of the recalled term (e.g. the correct order in which the terms were presented). As suggested by Huttner et al. (2019), the calculation was performed by the help of the levenshtein distance (or edit distance). This algorithm calculates the minimum costs of transforming a given sequence (in this case the sequence of the loci or terms) into an original one (Levenshtein, 1966). The costs increase by one for every operation necessary for the transformation (replace, insert or delete). The strict score was finally built with the following formula: strict score = 1 – (lev(i,j) / max ). The function lev(i,j) calculates the minimal costs to transform i into j. The denominator max represents the maximum costs that are possible for a defined sequence j. Due to this calculation of the strict score, the measurement is performed objectively and therefore suits the requirements for a statistical analysis.
Before the data was analysed, the participants’ input was corrected from spelling mistakes and pluralization (all words were presented in a singular form in the experiment). The statistical analysis was conducted using the open source software R (version 1.1.463). Table 1 gives an overview to the relevant descriptive statistics. While the experimental groups appear to be quite similar regarding the recall performance, the control group achieved higher scores. Moreover, the percentage of subjects who anticipated the original memorization and recall task is higher than expected. These issues will be covered in the upcoming analysis.

<table>
<thead>
<tr>
<th></th>
<th>uMOL</th>
<th>cMOL</th>
<th>CON</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lenient Score</td>
<td>.4565</td>
<td>.4250</td>
<td></td>
</tr>
<tr>
<td>Strict Score</td>
<td>.1054</td>
<td>.0500</td>
<td></td>
</tr>
<tr>
<td>Motion Sickness</td>
<td>3.304</td>
<td>3.50</td>
<td>NA</td>
</tr>
<tr>
<td>Anticipation</td>
<td>17 of 23 (74%)</td>
<td>14 of 23 (61%)</td>
<td>12 of 13 (92%)</td>
</tr>
</tbody>
</table>

Table 1. Descriptive statistics

The boxplots in figure 3 illustrate the difference between the control group and the experimental groups more clearly. Especially the strict scores differ substantially. The control group is characterized by a wider range within the middle 50% of participants and also achieved a higher maximum score. The strict scores in the experimental groups are closer distributed and indicate a more homogenous scoring performance. A similar phenomenon can be seen in the lenient scoring between the groups, although it is not as notable as in the strict scoring perspective.

Figure 3. Comparison of the memory performance.

5.1 Motion Sickness

All the participants of the cMOL and the uMOL group were asked to rate the motion sickness they perceived during this session on a five point likert-scale afterwards. A higher score indicated a higher perception of motion sickness. Since motion sickness is reportedly biasing the participants’ performance in virtual reality settings, simple linear regression models were calculated to examine if this effect also applies in this study. Hence, models were built with motion sickness as the independent and the strict and lenient scores as the dependent variables. A significant regression equation (on a level of p<.05) was found in the uMOL group (see table 2).
Furthermore, the influence of motion sickness on the lenient score in the uMOL group also shows a trend effect ($p < .1$, compare Legge et al., 2012). The negative coefficients (beta 1) support the theory that a higher level motion sickness decreases the subjects’ task performance. To improve the reliability of the analysis, all the participants with a motion sickness level above three were excluded in both of the experimental groups (leaving 15 participants in each experimental group). Thus, the effect of motion sickness could be excluded to a sufficient degree (new $p$-values in the uMOL condition: $p_{\text{strict}} = .4491$, $p_{\text{lenient}} = .281$). Note that the removal of the participants did not alter the significance in the cMOL group ($p_{\text{strict}} = .8967$, $p_{\text{lenient}} = .8835$).

### 5.2 Analysis of the Factor Anticipation

According to the descriptive statistics (see table 1), the vast majority of the participants anticipated the real task of recalling the presented items (cMOL: 61%, uMOL: 73%, CON: 92%). Therefore, it is reasonable to assume that the factor of anticipation of the original task may bias the possible effect of the treatment on the recall performance. In order to investigate this problem, two ANCOVAs were conducted to reveal possible effects and control the factor of anticipation in the analysis (with the strict and lenient scores as dependent variables). Before conducting the ANCOVAs, certain prerequisites regarding the data should be fulfilled. The recall performance (strict and lenient scores) was tested for their type of distribution using the Shapiro-Wilk test and Q-Q plots. All of the strict and lenient scores in the respecting groups are normally distributed except for one (cMOL – Strict score: $p = .2194$; cMOL – Lenient score: $p = .4491$; uMOL – Strict score: $p = .0035$; uMOL – Lenient score: $p = .2188$). Moreover, the Levene’s test indicated equal variance of the strict and lenient scores between the two experimental groups (variance of cMOL and uMOL – strict score: $F(8,6) = 2.2147$, $p = .1742$; lenient score: $F(4,10) = 0.3752$, $p = .9049$). The analysis of covariance of the lenient scores between the experimental groups while controlling for the factor anticipation shows a significant influence of anticipation on the treatment ($F(3,26) = 3.000$, $p = .04873$). The strict score is not affected by the factor anticipation ($F(3,26) = 1.047$, $p = .3884$).

### 5.3 Anticipation only Analysis

The previous analysis showed a significant covarying effect of the factor anticipation on the treatments in both experimental groups. Hence, eliminating the participants who anticipated the original memorization task would be next logical consequence in order to investigate the hypothesized effects. Unfortunately, this would result in an overall insufficient amount of participants for reliable quantitative methods. Therefore, in the following analysis only those participants are removed who anticipated the original intention. This way, the study’s outcome will slightly be biased by the factor of anticipation, but as shown above, the majority of the participants foresaw their task and the bias was only present on a significant level in one group only (see table 1). After eliminating the data of the non-anticipating subjects, the cMOL group has a remaining data set of eight and the uMOL group has a remaining data set of thirteen subjects.
In order to investigate H1 and H2, the cMOL and the uMOL group were again tested on their normal distribution. Shapiro-Wilk tests indicate that both, the strict and the lenient scores are probably normally distributed in the uMOL condition, while both recall scores in the cMOL condition are not (cMOL – Strict score: \( p = .5434 \); cMOL – Lenient score: \( p = .1895 \); uMOL – Strict score: \( p = .0099 \); uMOL – Lenient score: \( p = .0155 \)). Based on this results, a Wilcoxon Rank Sum test fits the requirements for a comparison of the means of the experimental groups (see table 3).

<table>
<thead>
<tr>
<th></th>
<th>Lenient Score</th>
<th>Strict Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W )</td>
<td>57.5</td>
<td>40</td>
</tr>
<tr>
<td>( W_{critical} )</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td>( p)-value</td>
<td>.7146</td>
<td>.4025</td>
</tr>
</tbody>
</table>

Table 3. Results of the Wilcoxon Rank Sum Tests

The results of the comparison of the lenient scores show that the null hypothesis cannot be rejected at this point. The level of significance is above .05 and .1. At the same time, the value of \( W_{critical} \) (53) is exceeded (\( W = 57.5 \)). Similarly, the results of the strict score analysis does not support a significant difference between the cMOL and the uMOL group.

6 Discussion

6.1 Recall Performance

The analysis shows that the recall performance was not significantly different between the experimental groups. This result motivates a further simplification of the VMP concept. In a use case where users do not have to be informed about the exact strategy or how it works, developers and practitioners may focus on other design aspects. Moreover, the results support the theory of the underlying mechanism of the MOL (Maguire et al., 2002), which seems to work independently from the exact knowledge about it.

Confusion may arise when comparing the cMOL and uMOL group with the control group. Memory performance of the control group is better compared to the performance of the other two groups with the help of VMP. First of all, this may be explained by the vast majority of participants who anticipated the real task as mentioned in section 5.1. Hence, they probably memorized the words more consciously which resulted as an overall better performance. Secondly, in section 6.4 we mention that the limitation of the experimental design could have led to the inevitable better performance of the control group. Participants were not informed of the memorization task, which may lead to concerns that this study has not much to do with the MOL mnemonic itself. Another reason could be found in the navigation method since Ragan et al. found out that complex control mechanisms might decrease memory performance in virtual reality settings (Ragan et al., 2012).

However, the benefit of this mnemonic is not the focus of this study. Instead, we focused merely on finding out the influence of conscious awareness of the existence of this method on recall ability. A further explanation of the better performance of the control group would be that the test environment was more similar to the learning environment in the control condition than in the virtual conditions. Craik and Tulving (1975) tested the retention performance of people under vs. above water, where words that had been learned under water were better recalled under water and vice-versa (Craik and Tulving, 1975). According to their study, it is possible that our test environment restricted the retention performance of the virtual groups. In real life learning scenarios, it is not practical to always have support from the VMP when applying the obtained knowledge. Hence, our test results comparing the virtual groups with the control condition could reflect real life learning situations and performance. This may be explained by the percentage of prediction of the real task. Almost all participants in the control group predicted the real intention of the experiment, which may cause them to memorize the
words consciously. Details referring to this problem were explained in section 5.2 and 6.2. Also in section 6.4 we mentioned that the limitation of the experimental design could have led to the inevitable better performance of the control group. However, the most important comparison for our study should be found between group cMOL and uMOL. In this study, a significant difference of the memory performances could not be found. Therefore, it can still be concluded that users can benefit from such learning scenarios even without the pre-knowledge of the MOL. As for the role of intention to memorize, which as mentioned was decreased for the cMOL and uMOL group, will be discussed in the following section.

6.2 The Role of Intention to Memorize

In our study, the cMOL and the uMOL group conducted this experiment session with a HMD in a VMP, whereas the control group conducted a traditional mental MOL session. According to the studies stating the improvement of task performance with high immersive environments (Witmer and Singer, 1998; Agarwal and Karahanna, 2000; Mania and Chalmers, 2001; Lin et al., 2002; Sowndararajan et al., 2008; Ragan et al., 2010), subjects of the VMP group (cMOL and uMOL) should have scored more than the control group. However, we can see an obvious disadvantage of these two groups both in strict scores and lenient scores. This might be explained by the factor that almost all participants in the control group revealed the true intention of this experiment and tried to remember these word instead of letting the learning process occur incidentally. It may imply the fact that the intention to memorize does have a positive influence on the memory performance. By considering this factor, we conducted our comparison with the non-anticipation condition only. Regardless of the application scenario of the MOL, in classroom settings or in self-learning cases, the intention to memorize objects or to learn would probably occur anyways. Overall, this study indicates that it would not be necessary to inform the users of the MOL before they use a learning application designed with the concept of the MOL or before they enter a VMP. Without conscious awareness of the using of this method or even of the existence of method, a mere exposure to visuospatial VMP would achieve probably the same memory performance.

6.3 Limitation and Future Research

One of our main goals in this paper was to determine whether it is necessary to inform users of the MOL before they enter a VMP. We compared two main groups of subjects by giving them the same fake task to ensure that subjects in group uMOL would not be conscious aware of the existence or the application of this method in the VMP. However, more than half of the subjects have anticipated the real intention of this experiment. Hence, it is important for future studies to refine the experimental design especially in the way how subjects should be briefed before the experiment. Thus, participants would be devoted to conduct another task and let the learning occur incidentally. In addition, studies could also be conducted to further investigate the role of intention to memorize when exploring a VMP. For instance, studies can be done to investigate the memory performance when learners receive the learning materials (e.g. botanical terminology) in classroom settings in a VMP without the intention to memorize. It would also be interesting to investigate the long term memory performance after a mere exposure to a visual spatial VMP using the MOL. Huttner et al. presented a data set that supported this superiority of the VMP induced long-term memorization performance (Huttner et al., 2019). Furthermore, comparing recall performance over time using a traditional MOL with an unconscious exposure to MOL may provide valuable evidence for researchers to further investigate the applicability of MOL. Results of such studies would not only provide the possibility to simplify the application of the MOL, it will also indicate whether it is practical and meaningful to use VMPs in classroom settings for learners aging from children to adult.

Another recommendation for future studies regarding VMPs is to include a control group that does not use the MOL to increase the probability of correctly judging whether the MOL was used in the experimental groups. Also, the measurement of motion sickness can be refined by a validated construct (e.g. the Kennedy-Lane Simulator Sickness Questionnaire).
7 Conclusion

The study expands the knowledge base of the MOL mnemonic in a VMP setting. We demonstrated that even without conscious awareness of the application or even the existence of the MOL the memory performance is not attenuated. Additionally, we support that the MOL is not particularly useful for remembering objects in order as Legge et al. (2012) also demonstrated in their study (Legge et al., 2012), which is contrary to previous research (e.g., Roediger (1980)).

The results of this study may provide valuable evidence for applying a VMP tool with the MOL for educational purpose in a more simple way. Nowadays, students are reluctant to use mnemonics because of the mental effort needed before they actually start to use them (Putnam, 2015). Our study shows the possibility of applying MOL even without telling users about this method. For classroom settings with children, where gamification and MOL may help with memorizing vocabulary and learning language (Rawendy et al., 2017), directly applying MOL in a VMP could ease the mental burden for younger learners and motivate them. Similar for classroom settings for higher education, the result of this study may inspire tutors and professors to freely apply the MOL in a VMP to help university students retain new concepts or memorize large amount of terminologies. As mentioned in previous sections, potential classroom settings would be economic and finance, physiology, medical science, biology, etc. (Bloom and Lamkin, 2006; Shaughnessy and White, 2012; Qureshi et al., 2014).

8 Appendix

The instructions to use the MOL (inspired by Legge et al. 2012):

*In this learning strategy, memory is built up from places and images. If we want to remember an object, we must first imagine it as an image and then place it in a place. If we want to remember a list of objects, we have to create a way out of these many places. The easiest way would be to imagine a familiar environment and place the objects in it. We can remember the objects by imagining navigating through the environment and collecting the list of objects in the original order.*

References


