Navigating Memory Palaces: The Role of Instructional Agents in Teaching the Method of Loci in Virtual Reality

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***Abstract*—With mnemonic techniques like the Method of Loci, learners are able to recall vast amounts of content reliably and for a long period of time. Students, however, often have little knowledge of such helpful techniques. Teaching the Method of Loci is challenging as it is based on mental imagery. The combination of Virtual Reality (VR) and virtual agents offers a solution for this, as the memorization method can be explained visually by the agent. To investigate the effects of this solution, we created a VR application where learners first design a series of virtual rooms and then place representations of memory objects into them with the agent's help. Secondly, they engage in recall through guided inspection, with the agent leading from location to location. We evaluated this approach in a comparative user study with 27 participants. Quantitative results show that learners who are introduced to the Method of Loci with the VR agent application initially show similar memory performance as students learning in traditional ways, but remember significantly better in a follow-up test one week later. Qualitative results indicate that with VR agents, students can practice the Method of Loci effectively. In the follow-up test, they were able to transfer it to new memorization tasks, where they performed more accurately, quickly, and confidently than their peers, even when not relying on the VR visualization. This highlights that VR and virtual agents can help teach mnemonic techniques to students. The results contribute towards the design of learning paths where students are first introduced to enjoyable learning methods by VR agents before being able to apply them efficiently.**

Keywords-Virtual Reality; Intelligent Tutoring Systems; Virtual Agents; Mnemonics; Method of Loci.

I. INTRODUCTION

Remembering and memorizing information is an important element of learning. Memorization clears up space in the limited working memory by moving information to the long-term memory [1]. This reduces the cognitive load and allows for complex thinking [2][3], improving task performance [4].

Despite this, many students apply ineffective learning methods [5] and are unfamiliar with mnemonic techniques that can improve their long-term retention [6]. One such mnemonic technique is the Method of Loci (MoL), which was already used in ancient Greece to memorize speeches and is still used today, e.g., by memory athletes [7]. The technique utilizes the brain's ability to create a mental map of our surroundings to remember and locate points of interest [7][8]: The student thinks of a familiar place, sometimes called a memory palace — their apartment, the classroom, or the path to university — and traverses it along a fixed route. On this path, the learner selects significant locations, e.g., on a desk, at an entry door or next to a lamp. Next, the learner imagines objects in these locations which represent the information to be memorized. To recall the information, the student can imagine walking the route again. At the specific spots, the placed mental images are recalled along with the associated pieces of knowledge.

Learners usually apply the MoL fully in their imagination without producing any tangible visualizations. This makes it challenging for educators to convey the method to students and to check whether they apply the method correctly. Here, Virtual Reality (VR) offers large potential by visualizing the imaginary parts of the MoL [9]. The learner can create and populate an arbitrarily large number of virtual environments with information. These rooms and the represented information can stay persistent, allowing the student to revisit them and to invite others to inspect their memory palace.

Moreover, guiding the student through the memory palace and the creation process has a positive effect on accepting the mnemonic technique [10]. A scalable way for such guides are virtual agents as simulated instructors [11]. The combination of the MoL with guidance of virtual agents is not well researched yet. Hence, the goal of this study is to research how VR and virtual agents influence students' ability to understand and apply the MoL. Our contributions in this paper are:

- A concept for integrating VR agents to guide learners in creating and using memory palaces in the MoL.
- A design and implementation of an open-source VR application to realize VR agents teaching the MoL.
- A user study about the learning effect, motivation and learning experience with VR agents conveying the MoL.

The remainder of the paper is structured as follows: In Section II, related research about the MoL in VR and instructional agents is presented. Section III describes our implemented VR system which users can utilize to build virtual memory palaces. In Section IV, this application is evaluated with users in a comparative study. Section V concludes the paper with a summary of central results and an outlook.

II. Related Work

Our study combines the mnemonic technique of the MoL with guidance by VR agents. We included studies with a user evaluation of the MoL in digital settings with a focus on VR systems. Moreover, we looked for studies about VR agents which were used as guides to cover both topics. The literature showed no studies combining the MoL and VR agents.

A. Method of Loci in Virtual Reality

Several studies investigated how to transfer the MoL to VR and digital worlds. For instance, Reggente et al. [12] applied the MoL to a desktop-based virtual environment. Their study compared users who are learning a list by freely placing 3D objects in the virtual world with those who could only observe the items in a static location. Learners who could place content freely in the environment were quicker and more accurate in recalling the list in forward and reverse order. This shows that humans' spatial memory also works with virtual worlds after learners have familiarized themselves with the environment.

Going beyond 2D screens, Huttner and Robra-Bissantz [13] and Krokos et al. [14] reported improved recall accuracy with the MoL in VR and increased immersion compared to desktop experiences. Participants were also significantly more willing to apply the MoL in VR [13] and reported higher spatial awareness, even though they were previously unfamiliar with VR Head-Mounted Displays (HMDs) [14].

Similar results were also presented by Moll and Sykes [9], who compared traditional learning methods with a VR-based MoL. The VR system led to significant improvements of 20.4% and 22.2% in recall compared with traditional learning methods in the two repetitions of the experiment, respectively. Moreover, the authors observed that participants acquired varying understandings of the MoL after a brief textual explanation. This led to differences in applying the MoL and influenced the recall success, underlining the need for a guided visual introduction to this mnemonic technique.

B. Virtual Agents as Guides

The literature also examines how virtual agents can mimic human guides and help in training scenarios. For instance, Hammady et al. [15] apply them as a MR museum guide. By utilizing storytelling, visualizations and audio narration, the agent leads the user through a series of waypoints while explaining the exhibitions. Because of the agents, users enjoyed the experience more and stayed longer in the museum.

The simulation of humans by virtual agents was also investigated by Bickmore et al. [16] in a presentation training application. In their study, the agent acts as a co-presenter so that the user can practice public speaking. Rated presentation recordings show that users significantly improved the quality of their presentations with the support of the agent. Moreover, non-native English speakers increased their confidence.

A common denominator of these studies is the high user satisfaction with the interaction with agents and the agent's ability to support the task performance. This is also supported by our previous studies where agents demonstrate assembly tasks [11] and visualize actions for accessible language learning [17]. Interactions with the agents were intuitive to users, leading to a high usability score of the applications. In the language learning use case, the performance was comparable to traditional vocabulary learning, but the agents caused a higher engagement and enjoyment [17].

These results highlight that VR agents can turn learning tasks into motivating experiences. This makes them a promising tool for conveying the MoL to learners.

III. Realization

In order to gain insights about the MoL with virtual agents, we implemented an open-source application (https://github.com/rwth-acis/MR-MiRA-Method-of-Loci-App) for the Meta Quest 2 and 3. The system allows users to set up a virtual environment in VR and fill it with elements for memorization. A virtual agent advises how to use the MoL and guides through the created memory palace.

A. Used Technologies

We developed the system using the Unity 3D engine and the Meta Software Development Kit (SDK). The simulated guides are created with our virtual agents framework [11]. With this resource, we can quickly integrate virtual agents into a project according to our reusable toolkit structure [18]. Developers can define the agent's behavior by sending tasks to the agent. We adjusted the visual appearance of the agent by loading a model from the ReadyPlayerMe service. Objects in the environment are prepared and modeled with the 3D software Blender.

B. Learning Workflow

Users progress through several stages: the setup phase, the memory forming phase and the guided repetition phase.

1) Setup Phase: During the setup phase, the learner constructs the virtual rooms. The overall shape of each room reflects the dimensions of the user's real room using the spatial map of the Meta Quest 2 and 3. The HMD's virtual boundary system also highlights real-world obstacles. Thus, the user can comfortably explore the space and grasp its spatial layout.

The user can select furniture objects in a menu and place them in the environment to personalize the space and to form an intuitive understanding of the room's structure. The furniture can either be placed using the Meta Quest's controllers or by direct hand tracking. To visualize the touch interactions of the hand, the system streams the HMD's camera feed, extracts the user's real hands from it, and displays them in VR.

During the setup of the room, the virtual agent follows the user. Upon first use, the agent teaches about the possible interactions, how to find furniture objects, and how to place them. It also encourages the user to place a sufficient amount of objects and to create multiple rooms so that enough content can later be memorized in the space.

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After setting up one room, the user can create and furnish further rooms. Within one virtual memory palace, the created rooms are automatically connected via color-coded doors. Purple doors indicate that the learner progresses further into the memory palace, whereas green doors lead back to previous rooms. The user can teleport to the connected room by touching the doors. This creates a sequence of rooms where each one can be individualized and look distinct. Through this setup, the user is nudged to create a linear route for the memory forming process, as recommended for the MoL.

2) Memory Forming Phase: After furnishing the rooms, the memory forming phase starts. Here, users can place 3D objects in the room to represent pieces of information to memorize. We will refer to these 3D objects for the remainder of the text as *information objects*. These information objects can be selected from a list of 103 objects, categorized into animals, people, cars, food and more. Hence, the user can choose freely how to visually encode the items to memorize them. To further enhance the memorability of the information objects, some of them have sounds attached to them like the siren of an ambulance, making the learning experience multimodal.

The information objects have a different visual style to distinguish them from the furniture, as depicted in Figure 1. Whereas the furniture has wooden textures, the information objects have a colorful low-poly style to catch the learner's attention. An optional mode grays out all room-related furniture, so that all information objects are highlighted at a glance.

Figure 1. An example of a room in a memory palace. Information objects are placed on the furniture.

The virtual agent advises on the process of the MoL while the user populates the room with information objects. It suggests suitable 3D objects to represent the pieces of knowledge. Moreover, it monitors the number of information objects in the space, warning the user to proceed to another room if the space becomes overloaded with information. Once all information objects are placed, the agent guides the user through the entire memory palace to establish a fixed route.

3) Guided Repetition Phase: This guidance activity leads to the guided repetition phase. The user and the agent start at the first placed information object. Then, sequentially, the agent walks to the next information object and points at it as depicted in Figure 2. A spotlight above the object is activated to draw attention to it. Once the user confirms the step, the agent proceeds to the next station in the route. The tour can be repeated multiple times to manifest the memory of it. This setup enables a spaced repetition approach. Learners can revisit the memory palace at any time since the application saves the spatial configuration of the furniture and the information objects. Spatial anchors ensure that the placed content remains at exactly the same physical locations since the virtual room's dimensions relate to the real room. The positional data are stored as a JavaScript Object Notation (JSON) file and can, therefore, also be shared with other learners.

Figure 2. A screenshot from the application, showing the agent pointing at an information object represented by a pine tree.

IV. EVALUATION

The implemented application was evaluated to assess the resulting understanding of the MoL by measuring: recall, usability, motivation, ability to apply the MoL, time efficiency, and application performance based on the number of objects.

A. Setup

Using a between-subjects design, the VR group, who used the Meta Quest 2 or 3, was compared to a control group that learned without technical support. The learning materials consisted of a list of 15 objects, a short story and a 20-digit number. Figure 3 depicts an overview of the study's procedure. Participants in the VR group received an introduction to the MoL, designed six to ten rooms with furniture and were given 40 minutes to learn the provided information, by placing information objects along a chosen path through the rooms. At each step, the agent supported the users and explained the procedure. After placing the information along the path, the agent helped revisit the rooms in the correct order of the loci. The control group was allowed to learn with their own methods, and had to describe them afterwards.

After the learning sessions, the participants were asked to answer several questionnaires: A knowledge test where they had to recall the list, answer 16 questions regarding the story, and state the learned number. They also answered 30 questions of the Intrinsic Motivation Inventory (IMI) [19]. The VR group additionally rated the application on the System Usability Scale (SUS) [20]. To assess the long-term memory performance, participants answered a follow-up test one week later. It consisted of the same recall tasks and four new questions. To test the understanding and transfer capabilities of the MoL, the VR group was tasked to learn another list of 20 words, using the MoL without VR support. The control group had to learn the list with the same method as in the prior week. Both groups had ten minutes of learning time.

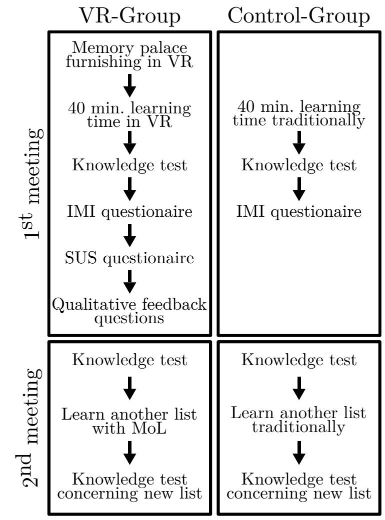

Figure 3. A graphic visualization of tasks and questionnaires of the evaluation.

B. Demographics

In total, 27 participants took part in the evaluation. 14 persons were in the VR group. Three of these participants were excluded in the analysis of the knowledge tests since one had difficulties with the teleportation and did not use the application till the end, one did not interact with the application, and one had difficulties in understanding the language. 13 participants formed the control group where one person did not take the second knowledge test.

1) Virtual Reality Group: The VR group consisted of nine women, three men, and two other genders, between the ages of 20-58 years, with an age average of 27.4 years. Ten of the participants were students, three employees, one was an apprentice. Seven persons had a background in computer science. Participants rated their VR knowledge with 2 out of 5; four people had used a VR HMD before. They rated their previous knowledge of the MoL on average with 1.6 out of 5; only one person had applied it before. Participants assessed their frequency to memorize during learning with an average of 2.9 out of five. They deem such memorization activities reasonable with an average of 3.4 out of five. Moreover, they rated their subjective concentration levels during the study with an average of 3.4 on a five-point Likert scale.

2) Control Group: Eight women and five men were part of the control group, aged between 20 and 62 years with an average of 32.2 years. Seven of the control group were students, four working, one an apprentice and one retired. They rated their required memorization frequency with 2.5, the memorization reasonability with 3 and the subjective concentration levels with 3.

C. Results

We collected results about the retention success and the learning efficiency. We analyzed the system's usability and the user feedback. To study the impact of the instructional agent, we measured the degree to which learners applied the MoL after using the system, as well as their motivation.

1) Knowledge Tests: The knowledge test checks the recall of the list, the story and the 20-digit number. To grade the list answers, the sum of differences between the recalled position and the actual position is added as negative penalty points. A wrong or missing word resulted in -5 penalty points. The VR group was slightly better than the control group with 93% of the maximum points compared to 90.6%, as shown in Table I. For the story questions, each correct answer resulted in one point and missing details in 0.5 points. The VR group recalled slightly more content from the story. We graded the number in the same way as the list. The VR group reached 84.3% of points compared to 85.6% in the control group.

TABLE I. RESULTS OF THE KNOWLEDGE TESTS ABOUT THE LIST, STORY, AND NUMBER FOR BOTH MEETINGS.

	Factor	VR	Control
1st Meeting	Points List	-5.286	-7.077
	Performance List	93%	90.6%
	Points Story	14.2	14
	Performance Story	88.6%	87.5%
	Points Number	-15.8	-14.4
	Performance Number	84.3%	85.6%
2nd Meeting	Average List	-17.1	-11.6
	Performance List	82.9%	88.4%
	Points Story	16.1	14.7
	Performance Story	80.5%	73.3%
	Points Number	-28.4	-28.1
	Performance Number	71.6%	71.9%

In the second knowledge test, the VR group recalled 82.9% of the list, and the control group 88.4%. For the story, the VR group recalled 7.1 percentage points more than the control group. In the four new questions, the VR group answered on average 75% correctly, while the control group only remembered 56.3%. The VR group was also better at remembering the order and items of the list. For the number, both groups were almost even with 71.6% in VR compared to 71.9%. In the story, 89.4% stayed the same as opposed to 78.1% for the control group. For the list and numbers, the control group's answers altered less than the VR group's answers.

The VR group was significantly better in remembering the new list at the second meeting than the control group according to a Mann-Whitney-U-Test with $U = 40$ and $p = 0.022$. Only two VR participants made errors, leading to a performance of 99.7% compared to 85.4% in the control group.

2) Time Efficiency: The answer times to questions on the knowledge test were tracked. In the first meeting, the VR group took 6 minutes 56 seconds, and the control group took 6 minutes 53 seconds. In the second meeting, the VR group was 1 minute 30 seconds faster than the control group with 6 minutes 28 seconds compared to 7 minutes 58 seconds. This time difference stems from the story and number questions. For learning the new list in the second meeting, the VR group took on average 6.4 minutes and the control group 9.9 minutes.

Thus, the VR group was faster and had better retention results when applying the MoL.

3) System Usability Scale: The usability of the application was evaluated with the SUS [20]. The system reached an overall score of 73.6, which is considered good [21]. Table II lists the individual averages for the ten SUS statements. In the table, the scale of the evenly numbered, negatively formulated statements is inverted so that a higher score always corresponds to a better performance.

TABLE II. NORMALIZED RESULTS OF THE SUS.

No.	SUS Statement	Avg. Score
1	Intended usage frequency	3.7
2	Low complexity	4.1
3	Ease of use	3.8
4	Independent technical usage	3.5
5	Integration of functions	4.3
6	Consistency	4.3
7	Learning speed	4.1
8	Convenience	4.4
9	Confidence	3.5
10	Immediate use	3.7

4) Motivation: 12 participants indicated a higher motivation for learning with VR. Of the other two, one experienced cybersickness and one based the decision on the kind of learned information. The detailed results are listed in Table III.

TABLE III. RESULTS OF THE IMI.

Subscale	VR	Control
Interest/Enjoyment	5.8	5.1
Perceived Competence	4.5	4
Effort/Importance	5.3	5.4
Pressure/Tension	3.2	3.4
Value/Usefulness	5.7	4.9

5) Qualitative Feedback Questions: The participants of the VR group were asked additional qualitative questions about the perceived performance scalability, perceived efficiency, and usability. Ten participants noticed no performance impact with a large number of rooms. Four persons mentioned that the app seemed somehow slower, and one of them felt the loading times impacted the learning experience. Eight participants thought the learning efficiency to be higher with VR, three without, and two similar between both options.

Eight users praised the intuitive controls. Users also commented positively about the menu staying in the field of view, the hand controls, the background sound, and the alignment of the rooms with the real world. The menu position was also critiqued twice, along with the weight of the HMD.

6) Application of the Method of Loci: 11 participants stated they remember the created rooms at least partially and can apply their MoL route in them. Ten learners think they can reuse the palace for new information, and the remaining four are worried they might confuse information. When asked about their preferred memory palaces, users mentioned their own flat, familiar routes, and an endless hallway. All participants gave a correct description of their MoL usage for learning the list at the second meeting. Furthermore, six applied additional cues like connecting elements to a story or existing objects.

The selection of information objects was helpful to nine participants, and two would like additional recommendations. 11 participants liked the help of the agent; two thought it was not necessary. Furthermore, 11 participants praised the sounds of the information objects, as well as the spoken instructions, while three would prefer additional written text, and one person found the sound distracting.

V. CONCLUSION AND FUTURE WORK

Many students are unfamiliar with memorization techniques like the Method of Loci. Since this technique is fully imaginary, conveying it to students requires a visualization of the memory palace and instructions on how to learn with it. This paper addresses this challenge by studying the impact of learning the MoL in VR with a virtual agent.

We implemented a VR application to visualize the memory palace and lead the learner through three phases: Initially, the learner sets up a virtual environment and furnishes it to become familiar with the rooms. Then, in a memory forming phase, the learner selects differently styled 3D models and places them in the virtual environment to represent information. Finally, the learner traverses the rooms again in a fixed route to strengthen the memories of the placed information objects and their associated facts. Throughout all three phases, a virtual agent assists the learner by explaining the placement controls, by instructing how to apply the MoL effectively and by guiding the learner through the rooms on a fixed route.

We evaluated the VR application in a user study with 27 participants. The study introduced participants to the MoL and compared learning with the MoL against familiar learning methods of a control group. After initially similar performance in the first test, the VR group significantly improved their recall results and answering time compared to the control group in a second test one week after the first. The VR group remembered more content from a story and were better at memorizing new content, even without relying on the VR application. This indicates that the VR application effectively introduces learners to the MoL, particularly if content is presented in a story form. Participants were also more confident at the second test in applying the MoL to new content without the VR aid. The VR group also showed higher interest and enjoyment in the memorization tasks, perceived themselves as more competent, felt less pressure, and attributed higher value and usefulness to memorization. Hence, learners experienced the learning process more positively with the VR application and after being introduced to the MoL. Overall, the combination of a VR memory palace and an explanatory agent leads to a higher performance and motivation.

The study focused on the overall learning effect of the MoL in VR with virtual agents. Future work could investigate the influence of the three phases of setup, memory formation and repetition individually: In the setup phase, it could be studied how the learning effect differs between the customized spaces of our application and pre-made environments. Here, different strategies to familiarize the user with the space could be explored, utilizing the agent. In the memory forming phase, a central question is how expressive the visualization tool needs to be. The list of pre-curated objects could be compared with more flexible Artificial Intelligence (AI)-generated images or 3D models. Thus, the agent can provide further creative input using an Large Language Model (LLM). Future work could aim to quantify the effect of AI support on memorability. Similarly, the repetition phase could utilize LLMs to generate a memorable route autonomously that the agent can then present to the learner. Future work could also repeat the study with a larger sample size to increase the statistical robustness.

All in all, the study demonstrated an effective concept for integrating virtual agents into a VR learning application to convey the MoL. With explanations by the agent, learners became familiar with the memory technique. This effect becomes evident as learners increased their retention abilities and recall speed in memorization tasks after using the VR application. These results are promising as they contribute towards a scalable, individualized digital solution which introduces students to more efficient and enjoyable learning methods.

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