The Art of Loci: Immerse to Memorize

Anne Vetter, Daniel Götz, Sebastian von Mammen
Games Engineering, University of Würzburg, Germany
{anne.vetter,daniel.goetz1}@stud-mail.uni-wuerzburg.de, sebastian.von.mammen@uni-wuerzburg.de

***Abstract*—There are uncountable things to be remembered, but most people were never shown how to memorize effectively. With this paper, the application The Art of Loci (TAoL) is presented, to provide the means for efficient and fun learning. In a virtual reality (VR) environment users can express their study material visually, either creating dimensional mind maps or experimenting with mnemonic strategies, such as mind palaces. We also present common memorization techniques in light of their underlying pedagogical foundations and discuss the respective features of TAoL in comparison with similar software applications.**

I. Introduction

Before writing was common, information could only be preserved by memorization. Major ancient literature like The Iliad and The Odyssey were memorized, passed on through generations, and finally written down. Just like poets, even Cicero relied on mnemonics to recite his speeches, making use of humans' spatial memory. We are very efficient in remembering images and locations, especially compared to forcing ourselves to remember information without obvious inherent order [1]. However, spatial memorization requires creativity, critical thinking and, furthermore, good visualization skills, which is especially difficult for novices [2]. In order to lower the barrier of entry, the VR application TAoL was developed. In TAoL, the user/player is empowered to intuitively navigate and design spaces to support his memorization efforts. Underlining the aptness of VR for such a task, constructive environment design has previously been highlighted as the "hidden curriculum of VR´´ [3]. In this paper, we motivate the design of TAoL based on requirements that have been identified as the basic ingredients of memory training.

II. Memory Training Requirements

In [4], several requirements from cognitive psychological and constructivist learning theories for enhancing the memorization process are presented: One needs to perceive a piece of information and focus on it, in order to absorb it. Therefore, aids to support perception and attention (R1), such as placing important information in the middle of a user's field of view, should guide the memorization process. The absorbed information needs to be encoded and stored for future reference. The former can be assisted by encoding strategies (R2) such as multi-modal presentation of the information to stimulate multiple perception channels. The latter benefits from repetition (R3) and organization (R4) of the information. Conceptual models (R5) such as visualizations are also beneficial. Recall is often just the first step, and assistance during comprehension (R6) of the information, e.g. by means of verbalization, should follow suit. Due to the heterogeneity of learners, the applied process and methods should be individualized (R7) and strike a productive balance between user's choices and imposed learning activities (locus of control) (R8). For example, users should be able to control the pace of learning. Learning environments should arouse the intrinsic motivation of the user (R9). Fostering an awareness of the learner's cognition and thus reflection on their learning process and strategies is also beneficial (metacognition) (R10). Further, a constructivist learning approach can be realized by the means to create artefacts such as representations, symbols or cues (R11). Finally, cooperative and collaborative learning environments can benefit the learning process (R12).

978-1-7281-4533-4/20/$31.00 2020 European Union

III. Learning Strategies

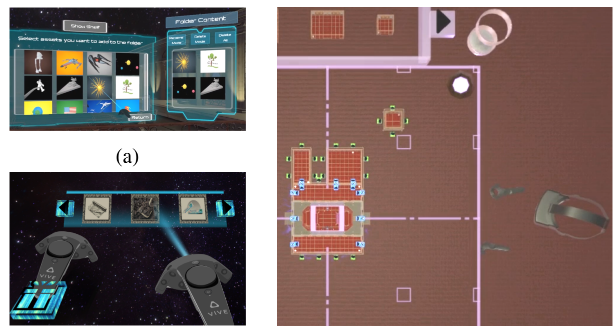
As hinted at before, it is common that individuals approach memorization in accordance with individual learning *styles* that may favor visual, aural, verbal, physical, logical representations, social or solitary contexts or any mixture thereof [5]. In contrast, learning *strategies* are adopted when studying. The most common learning strategy is *rote learning*, which is basically mass repetition until one is able to recite some information. But studies suggest that relying on more elaborate strategies aids in longer-term storage and offers higher potential for retrieval of knowledge. *Flashcards* present another learning strategy, where questions and answers are written on the two sides of a card. Stacks of flashcards capture sets of information that can first be learned one at a time and later recited. Spacing the cards in the stack in accordance with one's learning achievements provides for an optimized memorization process. The memorization strategy of *interleaving* motivates establishing connections between individual bits of information, for instance keywords. This is commonly practiced when drawing semantic network-like mind maps. As these maps are created by the learner, the connections are meaningful at a personal level and can therefore be easily recognizable and effective. Finally, memorization can be strategically realized by deploying so-called *mnemonic devices*, i.e. by mapping information into rhymes or word patterns that are easy to remember [6]. In order to memorize more complex information, mnemonic devices such as the Person-Action-Object (PAO) systems can be used. For instance, in order to memorize large numbers, each digit can be encoded as a consonant sound and associated with a person, action and object. On the other hand, more abstract content might be organized using chain-type mnemonics, like incorporating keywords in a story (story mnemonic) or linking them using an image that connects them to another (link mnemonic). The popular method of loci, or mind palace technique, represents information as images and links them to locations such as one's private bedroom or imaginary spaces. Visiting these places again later, one re-collects the associated information. Closer analysis of the requirements introduced in Section II reveals that the requirements of encoding (R2), repetition (R3), organisation of information (R4) as well as the use of conceptual models (R5) strongly vary for the different memorization strategies. We summarize these findings in Figure 1: In rote learning, no particular way of organization, encoding or conceptualization is fixed. When using flashcards, one engages more and improves recall in comparison to rote, especially when combined with spaced repetition [7]. While it increases performance in addition to reducing the cognitive load for the user, it improves on the repetition front, but neither organisation, encoding or conceptual models are incorporated. Even mind maps have to be recited to be memorized. But first, one organizes the information, building a structured map that suits one's understanding. Encoding the keywords beforehand is not required. The result is a visualisation of connections, and therefore a conceptual model, that serves as summary and aids fast repetition. While mnemonics are proven to be efficient in terms of recall, they still require repetition. There are strategies "for organizing and/or encoding information through the creation and use of cognitive cuing structures." [6]. Accordingly, Organisational Mnemonics unitize information into a connected whole, for better retrieval, while Encoding Mnemonics are applied to the material to fit in those structures. By these means, one creates a memorable visual model, that conceptualizes the data for increased long-term retention. With this individual, fun way of repetition, all points of the evaluation are satisfied.

	Rote	Flashcards	Mindmaps	Mnemonics
R3 repetition	✓	✓	✓	✓
R4 organisation	✗	✗	✓	✓
R2 encoding	✗	✗	✗	✓
R5 conceptual models	✗	✗	✓	✓

Fig. 1. Evaluation of learning strategies with respect to memory training requirements.

IV. TAoL Design

Research suggests that in VR people felt more immersed and confident, made fewer errors and statistically improved their performance when using the mind palace technique [8]. Moreover, engagement, positive emotions, which are especially important for effective learning, as well as recall are also improved in VR [9]. Experiences of presence and the feeling of embodiment can further enhance learning, as it facilitates embodied cognition [10]. Considering these facts, we chose an immersive design of TAoL. In a first prototype, the user could compose collections of imported low-poly 3D models [11] and 2D images at a central *visualization station* (Fig. 2(a)) that would be available in an *object browser* (Fig. 2(b)) attached to one of the VR controllers while navigating the environment. The objects could be moved, e.g. from browsing contexts to the virtual environment, by simple drag and drop initiated by pointing and clicking. Grabbing an object, it would impose the grabbing hand's position and rotation on the object, whereas changing the distance between both grabbed controllers would change the object's scale. Objects could be deleted again by dragging them into a virtual garbage bin. Mnemonic traces could be drawn using a secondary button on the controllers. The environment itself was represented as a miniature model where the user could add, remove and re-arrange rooms of the mind palace he was immersed into (Fig. 2(c)).

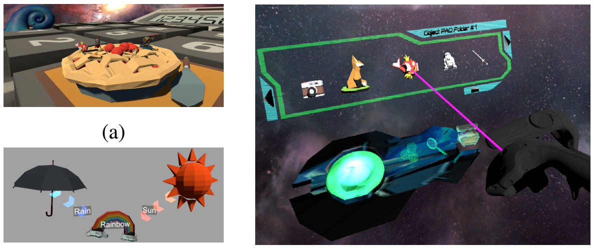


(a) (b) (c)

Fig. 2. Screenshots of the first TAoL prototype.

We re-designed the TAoL application to meet the requirements identified in Section II and to support more learning strategies (Section III). The most influential change was the conceptual unification of rooms and objects. Instead of pre-defining how, or even whether, a mind palace should be built, we made it possible to teleport onto arbitrary objects' surfaces by scaling down or up the user's avatar's size accordingly. Objects spawned within the respective coordinate frames are automatically scaled as well which allows for quick creation of spatial mnemonic hierarchies (Fig. 3(a)). In the universe of mathematics, there could be worlds for subtopics like linear algebra or analysis. Each of them could consist of further sub-hierarchies. E.g. 3(a) shows a mind palace for geometrical constants (the calculator) with mnemonics for the Golden ratio (shell) or Π. Their values are encoded using a PAO system and are placed as children in the world hierarchy.

We also decided to provide all the functionality to design and mange one's mnemonic space at the user's finger tips: The object browser can expand to browse large libraries of objects and to define sub-collections (Fig. 3(c)), and designed scenes can be stored into pages of a virtual book (and retrieved from there as well) . In addition to general improvement of the interactions, we introduced the gesture of "throwing behind" to delete an object, and we added a means to label any connections or objects that would appear like tooltip information (Fig. 3(b)).



(a) (b) (c)

Fig. 3. Screenshots of the second version of TAoL.

V. State-of-the-Art Comparison

In this section, we compare TAoL to three distinct state-of-the-art software applications that support or train memorization based on the requirements introduced in Section II. From a large number of according solutions, we selected Anki, XMind 2020, and Munx. Anki, is a widely used, open-source multi-platform application that digitizes the flashcard method [12]. Text, audio and images can be arranged on the cards, which can be shared across multiple devices and learned according to an integrated spaced repetition algorithm. XMind 2020, is representative of numerous professional mind mapping softwares. It is a subscription-based software that allows its users to create and share mind maps [13]. Munx is a free-to-use VR and desktop application in which users can load and arrange objects from a large library, create associations between them, save and share these creations [14]. Munx is mainly designed for creating mind palaces and part of a delivery pipeline for commercial online courses. As all the presented applications, including TAoL, focus on memorization rather than understanding the material, none of them provides the means to fulfill the comprehension criterion (R6). As R2 to R5 are primarily related to the deployed learning strategy, they have already been considered in Section III. Hence, we consider the different software solutions with respect to the remaining requirements R1 and R7 to R12 in the subsequent paragraphs.

A. Anki

Anki makes the user focus on relevant data relying on an integrated spaced repetition algorithm (R1). Cards and daily workload can be configured, but no further individualization is possible (R7). Guidance and customization meet the criterion of the locus of control (R8). The user might feel motivated when the cards of the day are repeated. But for strong engagement (R9), the learning process should be further incentivized. Strong metacognition aids are provided (R10) as one clearly sees the results of one's efforts, next to a great distribution of work load. The flashcards partitions the contents but no mnemonic representations are created. Thus (R11) is not attained. Means for collaboration (R12) are partly realized as card decks can be shared. Anki improves the mere flashcard learning strategy in terms of organisation by adding structural options.

B. XMind 2020

XMind 2020 provides simple, clear layout and authoring tools to quickly design well-structured mind maps. Answering to (R1), one does not lose focus. The required individualisation is realized to some extent (R7), as this application only supports one learning method but provides several ways for customization. Users can express themselves freely within this creative sandbox, but the guidance does not exceed example mind maps. Therefore the locus of control (R8) is partly balanced. While the ease of creating and reviewing aesthetic mind maps may be encouraging, the software is not created for entertainment. Hence, it goes only half way in terms of motivation (R9). Furthermore, the program does not provide metacognition aids (R10). However, when building a mind map one certainly creates an artefact of the material learned, thus the construction criterion is satisfied (R11). The collaborative approach (R12) is partly realized, as users can share their masterpieces. In conclusion, XMind 2020 offers an effective approach to digitalize the mind mapping technique. Therefore, the criteria in terms of repetition, organisation and conceptual models are satisfied, according to the first comparison.

C. Munx VR

When entering the space of Munx in VR, one can easily focus on the presented mind palace. The desktop version's UI can be confusing, though, as the UI is not attached to the camera. Hence, the first requirement (R1) is only partially fulfilled. While numerous customization options are provided, the software is strongly focused on a single way to organize mnemonics, using the Quincunx pattern. Thus individualization (R7) is only possible to some small extent. Despite some design limitations, the locus of control is still partly balanced as the very basics of mind palace design is conveyed through examples (R8). While Munx learning experience in VR is captivating, its controls can get frustrating and negatively affect one's motivation (R9), as different functions such as spawning, moving, deleting, etc. require switching different tools, which can be rather difficult, especially considering the desktop version's keyboard shortcuts, or the fact that some basic functionality such as simple object transforms are not explained. Like XMind 2020, Munx does not aid in metacognition (R10). As mind palaces are creative abstractions of some information, the criterion of construction (R11) is satisfied. Even if one can buy pre-made constructions through Munx, real collaboration (R12) is not attained. Finally, every aspect of learning strategies is satisfied, as all the other ones can be realized by the functionality provided for creating mind palaces.

D. TAoL 1^{st} Prototype

In the early TAoL prototype, the user interface aims at naturalness, keeping the interactions simple and relying on well-established patterns. Together with the immersive view on the mind palace, appropriate focus can be provided (R1). Mind palaces and PAO systems can freely be configured. However, as TAoL is limited to a subset of mnemonic strategies and repetitive rooms, comprehensive individualization (R7) is not possible. Guidance in TAoL is limited to given examples and a tutorial space, so the locus of control (R8) is only partly addressed. The greater the mastery of TAoL, more complex and innovative can one's mind palaces become. In combination with the inherently personal relationships the user introduces and the freedom to design the spaces, the three pillars of fun described by Koster [15], namely relatedness, competency and autonomy are addressed by TAoL. Hence, we consider (R9) fulfilled. However, aids for metacognition (R10) are not incorporated. As construction is essential to mnemonics, every created mind palace is an artefact (R11) and can at least be shared in form of a savefile. However, as direct collaboration is not possible, the criterion (R12) is only partly satisfied. Focusing on the mind palace technique, all requirements for memorization strategies are fulfilled.

E. TAoL 2^{nd} Version

For the second iteration of TAoL, we further refined control and navigation mechanics. The achieved freedom in composing palace architectures further aids perception of information. (R1) is even better addressed as before. Due to enhanced customization, users are only limited by their imagination, expressed either using mnemonics or building 3D mind maps. These can be viewed from all perspectives, walked on, inspected in detail or zoomed out. Therefore, many possibilities for individualisation (R7) are provided. Because of this freedom, the software refrains from providing too much guidance, potentially limiting the user's mnemonic designs. Accordingly, the locus of control (R8) is only halfway fulfilled. With the improved sandbox-like experience, due to self-designed environments and refined controls, the rationale of the first prototype regarding fun and engagement (R9) applies even better now. The program notifies where repetition might be needed, by highlighting worlds that should be visited. Thus, aids in metacognition (R10) are partly provided. With this software, a universe of artefacts is created, while applying different strategies to the material. Therefore, criterion (R11) is satisfied. (R12) has not changed from the first prototype - save files can still be exchanged. Again, all requirements for strategies are fulfilled, but more mnemonic structures and even mind map-like constructions are supported.

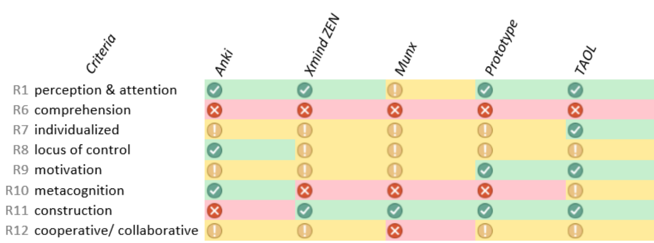


Fig. 4. Evaluation of learning software with respect to memory training requirements.

VI. Summary & Future Work

Based on a requirement analysis for memorization training motivated by pedagogical principles, we designed TAoL, an immersive software for creating mnemonic spaces. We compared TAoL's first and second iteration with state-of-the-art software solutions that aim at supporting or training memorization. While all the inspected applications have extensive and mature features, none of them fully addresses the identified requirements. This also applies for our own proposed solution, yet especially its high degrees of engagement and individualization are unique at this point.

Even those design aspects of the presented solutions that already contribute to the fulfillment of requirements can be improved on. For instance, in TAoL, adding audio could increase focus (R1), fun (R9), mnemonic design opportunities (R11), etc. On the other hand, especially those requirements that have not been fully addressed at all, such as locus of control (R8) or collaboration (R12) should be considered as future work, due to their potentially great impact on memorization success. It may be possible to find rather generic solutions for them that might open up novel perspectives on memorization techniques and strategies, similar to the shown arbitrary placement of objects mind palace (sub-)spaces or as memory contents that allows for very versatile unification of memorization strategies. Finally, by conducting an experiment testing the effectiveness as well as user acceptance of TAoL and comparing it with other memorization strategies the hypotheses presented in this paper can be tested.

References

[1] J. Foer, *Moonwalking with Einstein*, 1st ed. New York, USA: The Penguin Press, 2011.

[2] J. Huttner and K. Robbert, "The role of mental factors for the design of a virtual memory palace," Aug. 2018.

[3] D. W. Bricken, "Learning in virtual reality," 1990. [Online]. Available: https://eric.ed.gov/?id=ED359950h

[4] S. M. Alessi and S. R. Trollip, *Multimedia for Learning: Methods and Development (3rd Edition)*. Boston: MA: Allyn & Bacon, Inc., 2001.

[5] S. Cassidy, "Learning styles: An overview of theories, models, and measures," *Educational Psychology*, vol. 24, pp. 419–444, Aug. 2004.

[6] F. S. Bellezza, "Mnemonic devices: Classification, characteristics, and criteria," *Review of Educational Research*, vol. 51, pp. 247–275, Summer 1981.

[7] R. Thomson and D. J. Mehring, "Better vocabulary study strategies for long-term learning," *Kwansei Gakuin University Humanities Review*, vol. 20, pp. 133–141, 2015.

[8] C. P. E. Krokos and A. Varshney, "Virtual memory palaces: immersion aids recall," *Virtual Reality*, May 2018.

[9] D. Allcoat and A. V. Muhlenen, "Learning in virtual reality: Effects on performance, emotion and engagement," *Research in Learning Technology*, vol. 26, Nov 2018.

[10] D. Parmar, "Evaluating the effects of immersive embodied interaction on cognition in virtual reality," Ph.D. dissertation, Clemson University, South Carolina, Aug. 2017. [Online]. Available: https://tigerprints.clemson.edu/

[11] (2020) Google poly. Google LLC. [Online]. Available: https://poly.google.com/

[12] Anki. [Online]. Available: https://apps.ankiweb.net/

[13] Xmind 2020. XMind Ltd. [Online]. Available: https://www.xmind.net/xmind2020/

[14] Munx vr: Memory palaces in virtual reality. Linguisticator. [Online]. Available: https://linguisticator.com/p/munxvr

[15] R. Koster, *Theory of fun for game design*. " O'Reilly Media, Inc.", 2013.