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Learning Languages and Complex Subjects with Memory Palaces

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Abstract. A memory palace is an ancient technique of using space as a way of organizing memories. It's a powerful tool for learning, retaining, and recalling large amounts of complex information quickly and effectively. In the middle ages, these techniques were widely used to learn and compose large texts and works of literature. In this paper, we present the fundamental theory behind memory palaces as the foundation for the project Macunx - a VR platform for building memory palaces to learn huge amounts in short time and with full retention - as well as the initial stages of its development. The paper concludes with a discussion of the future stages over the testing of the package with end-users for its final refinement.

Keywords: Memory Palaces, Cognitive Learning, dyslexia, spatial memory, Educational Games, Heuristics, Interactive Learning Environments, Virtual Environment, Head Up Display (H.U.D.)

1 Introduction

Spatial memory techniques as they can be broadly described – including the use of memory palaces, memory journeys, and the method of loci – systematically apply spatial learning to mastering knowledge-based material typically presented and learned through purely verbal, textual, and numerical formats. These techniques employ innate human ability to process, store, and recall large amounts of spatial information quickly and effectively with relatively little effort. By converting textual and numerical information into visual, experiential, and spatial information, we can learn, retain, and use that information faster than through other methods, including rote memorization, and pure drilling.

Spatial memory techniques have been attested for approximately 2500 years. They were used widely in ancient Greece and Rome for learning and composing works of literature and oration, often of great complexity. We have significant evidence from the Middle Ages of these techniques being used as a primary means of instruction in monastic education. Numerous descriptions of spatial memory techniques exist from the ancient and medieval world, including by such widely known intellectual giants as Cicero, Thomas Aquinas, and Hugh of St. Victor. We have yet more evidence of the intellectual feats performed through use of these techniques. In the Middle Ages, for example, it was standard for young pupils to learn all 150 Psalms of the Bible by both Psalm number and line number [1].

In modern times, spatial memory techniques have seen a resurgence in use. Memory competitions have become popular in recent decades, and memory artists have been known to perform incredible feats, including learning long strings of numbers, decks of cards, and other lists of facts [2]. The use of these modern memory systems, however, is extremely limited when compared with their ancient and medieval counterparts. Modern memory systems are used almost exclusively for simple data sets: in other words, information that can be presented in single, sequential lists. In ancient and medieval times, however, spatial memory techniques were used for learning and composing incredibly complex material.

Recent scientific studies [3] have shown the efficacy of the underlying principles of memory as a trainable skill, demonstrating that these principles can be learned and applied by anyone [4,5]. Successful application of memory techniques requires special training, but not any special innate ability other than that already possessed.

Most educators agree that the interactive nature of e-learning and mobile technologies increase the teacher and student communication. But to date, learning on social media and other e-learning platforms has been a poor substitute for classroom learning. To address this issue, several academic institutions have introduced *blended* [10] and *flipped* [11] learning strategies. In the former classroom strategy, students learn through a “blended” model of in-person (with a teacher) and technology-based instruction with some student control over time, place, path and/or pace of the curriculum.

Virtual reality can be used to support the purposes behind gamified learning since VR alters a person’s perception of reality by tricking the senses and providing artificial computer-generated stimuli [12]. However, tricking human senses can be much harder than tricking the mind. By using multimodality interactivity in relation to spatial domain for creating a believable experience, we can provide the sort of artificial stimuli that are good enough to prompt the mind to create and believe in its own illusion.

In this paper, we present the concept of using spatial memory palaces as a pedagogy toolkit. The paper focuses on techniques used to design the VR memory palaces, user experimentation and the initial development of the Macunx VR prototype [9] currently under the final development stages as part of an EU KEEP+ fund. The study concludes with a set of future steps and possible directions.

2 Memory Palaces: Challenges and Applications

As a skill, spatial memory poses a number of challenges when it comes to wide-scale adoption as a modern pedagogy. In order for memory techniques to be used widely, they need to be applicable to more than just lists of information. The majority of practical subjects – from science, to medicine, to languages – cannot be reduced to simple lists. The information is complex, and requires complex spatial structures for the successful application of memory techniques. This creates several challenges:

- For large-scale systems, there can be an enormous burden on the learner to keep track of and maintain large numbers of mnemonic images. If one of these images is forgotten, it is lost forever and the student must replace that image with a new one. This can cause frustration and can slow the learning process down.
- A common concern is running out of 'space.' It is recommended that students use spaces they know as memory palaces for specific subjects. The same space should not be used multiple times for multiple subjects. In other words, if you have used your house for one subject, you cannot use it again for another subject. This creates a burden of needing to identify and learn a large number of spaces even before being able to apply memory techniques.
- Memory systems for complex subjects require complex spaces, and these are difficult and time-consuming to describe and transfer orally. Training in memory techniques, therefore, can be a very hands-on, time-consuming, and un-scalable process. Learning to apply spatial memory techniques may actually involve walking students through a real physical space while creating imaginative mnemonics and reviewing them periodically.
- In transferring complex spatial structures for the purpose of learning complex subjects, it can be difficult to know whether a student has properly understood an oral description of the spatial layout. With imagined spaces, teacher and student could be thinking of two completely different layouts, but the differences might not be apparent in their dialogue.
- The structure of a memory palace for a complex subject is based on the subject itself. This means a subject matter expert who is also familiar with memory techniques must set up the structure of the space before a student can fill that structure with his or her own mnemonic images.

Owing to these challenges in training and using spatial memory techniques, it is no wonder that they are used almost exclusively today for learning simple sets of data. Wide-scale use of spatial memory techniques for learning complex practical subjects requires a specialized set of tools.

Virtual reality provides the perfect medium for spatial memory training. Students can generate their own mnemonic images using their imagination, but then actually see representations of these images in the form of 3-D models. The software can save both the models themselves, as well as their locations within the spatial structure. This removes a tremendous mental burden for the user, making it possible to create and remember memory palaces of a larger scale and greater complexity. Furthermore, users remember not merely something imagined, but something they have actually seen with their own eyes.

In virtual reality, an infinite number of new spaces can also be created, so users will never run out of space. Most importantly, however, spatial structures can be created and transferred between users. In other words, multiple users can step inside the same memory palace to understand how the space is set up for specific subject. This makes memory training and its application much faster, more effective, and easier to scale. This has been borne out both by Linguisticator's own first-hand experience, as well as academic studies [6].

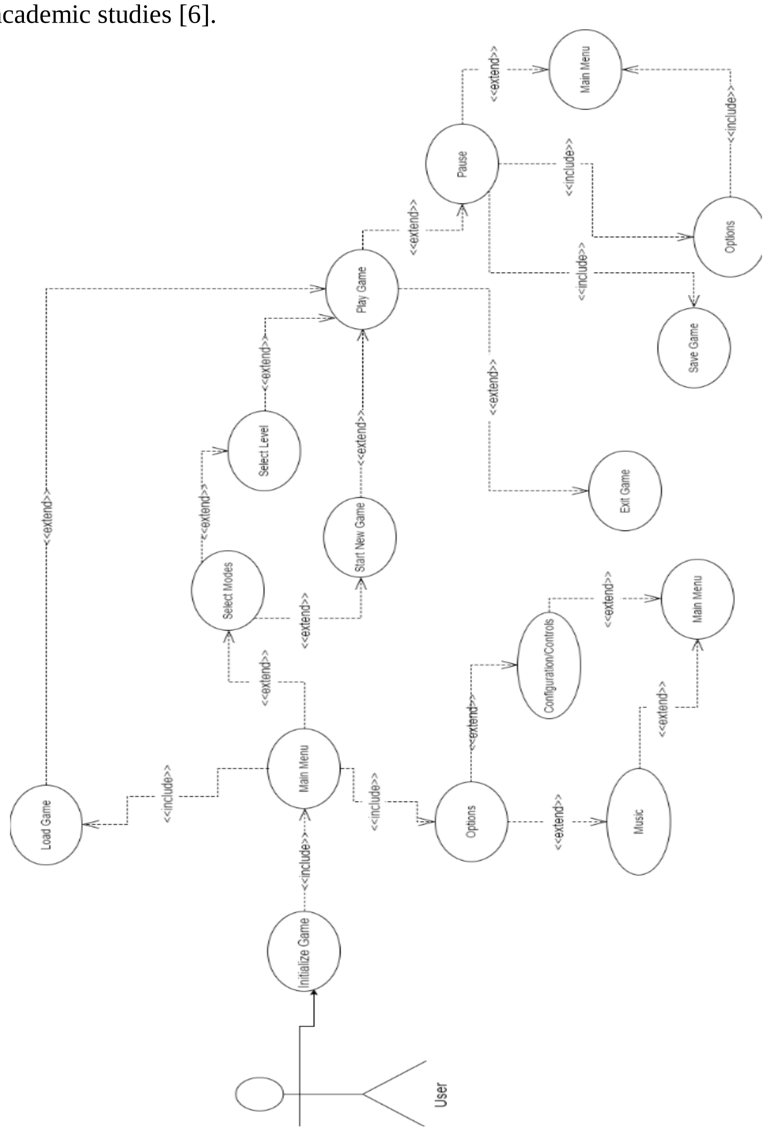

Fig. 1. Use case diagram of interactivity for Macunx VR

3 Memory Palaces for Dyslexia – Concept Testing

Throughout the spring and summer of 2016, Linguisticator Limited performed a number of trials with approximately 20 dyslexic children in Cambridge. Experimenting with both numbers and spellings, spatial memory techniques were used to circumvent and overcome many of the challenges posed by dyslexia.

The majority of students were between the ages of 10 and 14. Most did not know their own phone numbers, so this provided a good starting point for introducing spatial and visual memory techniques. Within 20 minutes to an hour, all children were able to recite their own phone number not only forwards, but also backwards without error. These results were achieved using purely imaginative memory palaces – no software or visual images were involved. Follow-up visits between one and three weeks later showed that the majority of children had retained 90 to 100% of the material learned in the first session [7,8].

The same techniques were applied to spelling with comparable success and retention. Children were taught to spell challenging words, such as 'beautiful.' By using images placed in space and connecting these images with some kind of narrative – all of which were generated by the students themselves – students transformed spellings of words into vivid and playful stories, each letter of which had a defined character with a specific location.

Preliminary results showed that these techniques unquestionably provided a viable way for dyslexic children to circumvent their learning challenges and use a different methodology to learn the same curriculum as non-dyslexic children. More importantly, however, it was observed that repeated use of spatial memory techniques for learning word spellings actually changed students' perception of text itself. Difficult spellings – once stored using a memory palace – no longer presented the same challenges in either reading or writing, even in entirely new contexts. A word that may have elicited hesitation, and phonetic sounding out each and every time that word was encountered, was subsequently read aloud without hesitation even in entirely new texts. More research is needed to confirm this change in perception, but the preliminary observations have been extremely encouraging.

Further work with dyslexic children has continued to yield impressive results. One 12-year-old boy, for example, has created a mnemonic system for numbers, and has learned Pi to 160 places. The student could repeat the digits both forwards and backwards, and was also using memory techniques to improve his spelling and written composition. In this particular case, the child has been using 3-D modeling software to aid his retention of his numeric systems. Improved results through the use of virtual spaces and mnemonics can readily be observed and have been reported as preferable and more effective by the student himself.

4 Macunx VR Prototype

The word Macunx is short for Magical Quincunx, and is a 2D design developed by Dr Aaron Ralby (Figure 2). This geometric pattern uses the quincunx (the shape of the 5 side of dice) to create a memory structure that allows you to learn 100 pieces of information in sequence and by number. The inspiration for the structure came from a 12th century treatise by Hugh of St. Victor on how to memorize all 150 Psalms by number and line number.

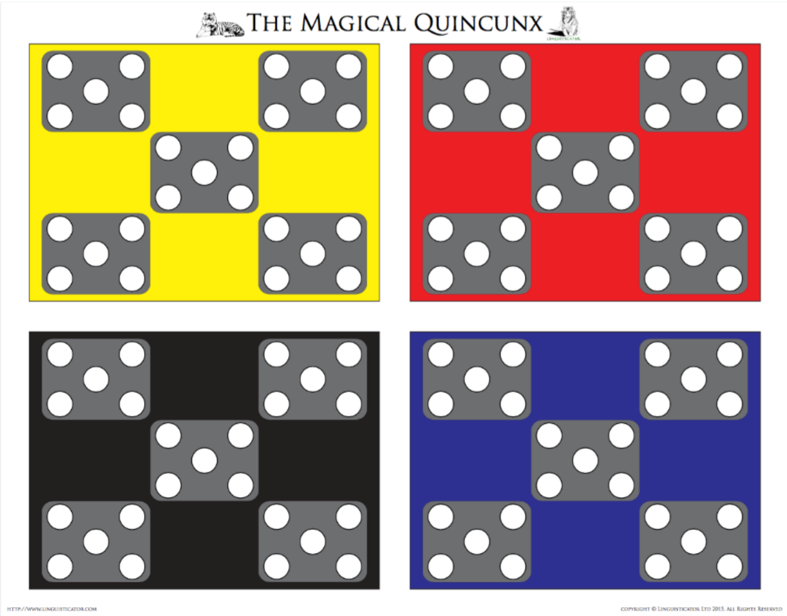

Fig. 2. As a 2D structure, the Macunx can be hung on a wall in your memory palace like a painting. This multiplies the amount of information you can store at each location by a factor of 100!

The proposed project will consist of three production stages:

- Stage 1: This includes the development of the Macunx VR prototype using Unity. The prototype will have the capability for the users to select objects from a database (create also their own database from loading models/images from local folders or the internet), deploy selective ones (a mechanism to include the most frequent used can be enabled on the User Interface - UI) on the panel – UI and then adjust them on relative locations within the VR Game-mode plane to establish VR memory concepts/palaces.
- Stage 2: Stage two will be based in stage one production. Memory palaces that will be used to simulate and test the stage 1 will be introduced with the method of tutorials to simulate step-by-step guide to the users of how to create their own Memory Palaces. This stage will include a menu system for the users to select category of building, for example: building walls, modifying the UI interactive menu, toping up libraries with new materials, selecting active libraries, loading previous Memory palaces and saving current ones, and finally other functionalities that the environment will integrate as part of the UI from the VR controllers.
- Stage 3: The third stage will include the integration of an online library for any user to save their own developed Memory Palaces lining them from their own space to the web space of Linguisticator Ltd. This will create a memory

palace marketplace, helping other users to be able to download pre-built spaces and us them/the subjects.

- Final mode for this project will include the availability of the user to export the current walkthrough of the Memory Palace on a mobile version and use it with the support of VR cardboard set- this will help potential lecturers integrate memory palaces in larger groups (classes) and produce a "Flip" learning classroom approach.

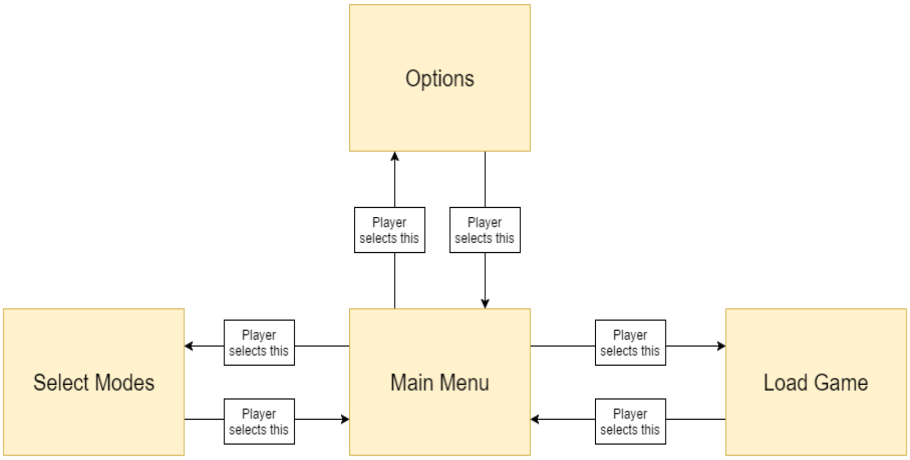

Fig. 3. User system modes and menu interactivity

5 Macunx Implementation

The prototype has been developed using Unity 3D game platform and at this stage is using the HTC VR Headset as the main interactive platform. Future development will include the deployment on Oculus Rift SDK3 as well for SAMSUNG Gear VR and Google Cardboard for final interactive lectures. The design of the framework is following the key-heuristics based on Koefeel et.al [13] research and some of them are summarized in Table 1 below:

Table 1. : Heuristics summary for MACUNX VR

No	Heuristic	Reference Source
1	***The player finds the application enjoyable and fun with no repetitive or boring tasks*** This is a very important heuristic because the objective of the game is to utilize VR in educational applications. The game will strive to be an alternative way of learning without it being overly repetitive that could cause more harm than good	**[14]**
2	***The program goals are clear. They should provide clear goals for the user as well as short term goals throughout game play***	**[14]**

	In the prototype, there will be clear goals to give the player as an indication of what they must do next without giving too much away. For example, in the tutorial level there will be instructions on how to use the VR controllers, headset and how to add objects into the game world.	
3	***Controls are intuitive, and mapped in a natural way; they are customizable and default to industry standard settings*** This heuristic is another important one as the controls are the key element to any game. Using the VR controllers are a new experience and the player's feedback will impact on the practicality of using VR in games. The controls will be relatively simple to pick up and play	**[14,15]**
4	***User is given controls that are basic enough to learn quickly, yet expandable for advanced options for advanced players*** The controls mapped on the VR controllers will be simple to understand and pick up. Later on, different modes would require more precise actions and speed to get the correct mnemonic in time.	**[14,16]**
5	***Screen layout is efficient, integrated, and visually pleasing.*** The game will mainly use 3D objects, which means the interfaces, game world and VR integration are key to the overall appearance of the game	**[14]**
6	***Navigation is consistent, logical and minimalist*** The game flow will be seamless as it does not require a lot of going through multiple options just to select an object or command	**[15,16]**

5.1 Tutorial Level Designs

For the tutorial level there will be 4 pedestals on which the player must place the correct mnemonic on. Voice narration on this level instructs the player on how to use the VR controls and explains any configurations if needed (Figure 4). The mnemonics for this tutorial are simple so the topic could be numbers from one to four. The player would have to navigate through the asset browser menu to find the correct mnemonic. Once they have completed it, the player could either remain on this tutorial level and play with the mechanics or go to the next level.

For level 1, there will be 6 pedestals on which the player must place the correct mnemonic on. This is will be treated as the easy level because it uses the player's knowledge from the tutorial level. They will be given hints on what mnemonic each pedestal needs so for this level the hints are formed as the beginning letters. For example "O" would stand for a mnemonic that starts with that letter. Just like the tutorial level, the player has to navigate through the asset browser menu to find the correct mnemonic. Once they have completed the level, they can progress to the next level. For level 2, there will be 8 pedestals for the player this time. The hints are descriptions that are specific to the mnemonic.

For example "vendor is often used to refer to someone selling goods". As with the previous levels, the user has to navigate through the asset browser menu to find the correct mnemonic. Once the user has completed the level, they can progress to the next level. For level 3, there will be 12 pedestals and the player must use their growing knowledge to find the correct mnemonic for each of them. The hints are mnemonics being used in the sentence so for example "Rubbish goes in the bin not on the floor". Similar with the previous levels, the player has to navigate through the asset browser menu to find the correct mnemonic and once they have completed the level, they can progress to the next level.

Fig. 4. Tutorial Levels Design- Level 1 (top right), Level 2 (bottom left) and Level 3 (bot tom right)

5.2 Object Interactivity

Using the VR HMD's can give the player motion sickness which is a risk that needs to be avoided for safety reasons. To counter this risk, a teleportation feature has been integrated that allows the user to travel safely within the game world without causing nausea. By setting up a camera rig, it will create a play area that uses the room scale of the room to use when interacting in the virtual world. Setting up the dimensions is dependent on the room scale but for now we will scale it to 300x225. Using the controller mappings, the user can assign a specific function to each button. For instance, teleportation requires the player to press down on the touchpad in order for a laser pointer to appear with an indicator showing where the player can travel. To confirm their destination, the player will then have to press the trigger button and they will be teleported to their area of choice (Figure 5).

As of right now, using the trigger button you can pick up an object and drop it by releasing the trigger button. In addition to during the interaction, this feature can also be used during teleportation while the user carries the object – this way, they don't have to keep teleporting to their destination to spawn the object.

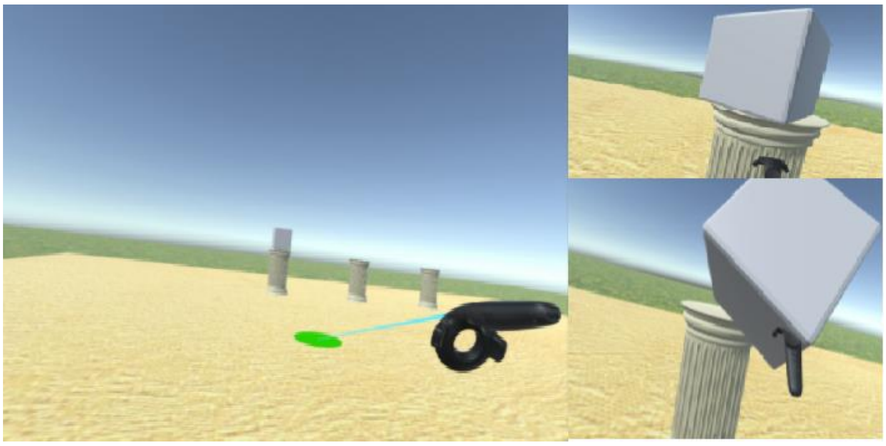

Fig. 5. Laser pointer to show how the user can move in the game world – User teleportation

5.3 Menu Libraries

The library system is once of the most important features of Macunx VR: users can select their own mnemonics to attach to the game world as part of an integrated menu in the HTC controller (Figure 6). The final project version will give the user the option to the user to top-up mnemonics via a menu interface library through local directory or the internet.

6 Conclusion & Future Experimentation

Based on Linguisticator's preliminary results with dyslexic children, as well as continued work with adult learners working on mastering foreign languages through memory techniques, there are a number of simple experiments that can be run with the virtual reality software in order to quantify its efficacy. In particular, spelling and literacy exercises for dyslexic children would be particularly illustrative.

Volunteer children between the ages of 8 and 14 with a confirmed diagnosis of dyslexia would be recruited via local schools. Baseline tests would be taken to determine children's ability to spell a series of 10 to 20 words. Children would also be observed reading aloud texts that contain these words, which would be specifically chosen because of their difficulty to spell. Children would then be randomly split into a control and experimental group.

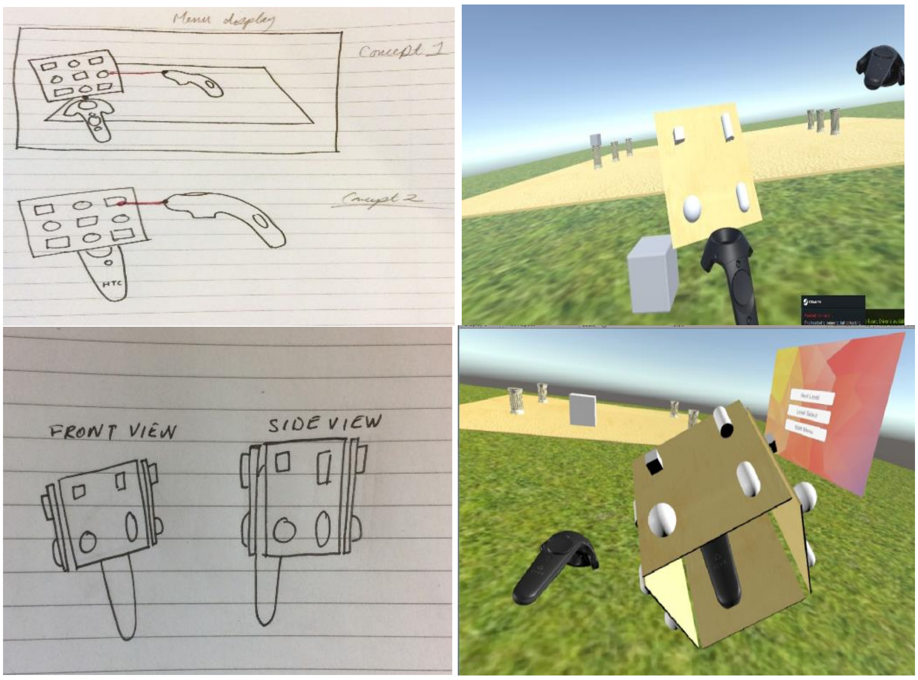

Fig. 6. User interface for selecting mnemonics

The control group would receive standard spelling remediation, involving repeated drilling of the same words. The experimental group would receive spatial memory training in virtual reality, learning to spell the same words. Both groups would be tested after the same amount of time in training, immediately after the training session has been completed. They would then be retested after a period of one week to determine rates of retention. Testing would involve active spelling of the specific words, as well as reading new texts with the same vocabulary. Testers would observe any difference in levels of hesitation or in children's need to sound words out as compared to the baseline tests before training.

Such a simple experiment would demonstrate the foundational principles of spatial memory as a viable option for circumventing challenges related to dyslexia. Further testing and observation could be conducted to monitor the long-term effect of such spatial memory training and how it can be used comprehensively to master more than just individual words, but rather entire subjects.

A prototype alpha version of Macunx VR will be available for testing with users by the middle of Autumn 2017. User experience feedback from both students and instructors who would like to work with the toolkit to create their own memory palaces as part of their teaching will provide further feedback for the final tuning of the platform by the end of April 2018. For the final package the intention is to release supplementary video tutorials to support beginner learners and instructors,

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