AR-Supported Mind Palace for L2 Vocabulary Recall

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Abstract—MnemoRoom4U is an AR (Augmented Reality) tool that uses a memory-palace strategy for foreign-language training. A memory palace helps information recall with the aid of object association in visualisations of familiar spatial surroundings. In MnemoRoom4U, paper or digital flashcards are replaced with virtual notes containing L1 words and their L2 translations that are placed on top of real physical objects inside a familiar environment, such as one's room, home, office space, etc. The AR-supported notes aid associative memory by establishing a relationship between the physical objects in the user's mind and the virtual lexis to be retained in L2. Learners first set up a path through their familiar environment, attaching virtual sticky notes—each containing a target word to be memorised together with its corresponding source-language translation—to real-life objects (e.g. furniture in their homes or offices). They then take the same path again, reviewing all the words, and finally carry out a retention test. MnemoRoom4U is a technological artefact designed for specific didactic purposes in the Unity game engine with the ARCore augmented-reality plug-in for Android. This work takes a Design-Science approach with phenomenological, exploratory underpinnings tracking back to the efficiency of spatial mnemonics previously reported quantitatively and combines it with AR technology to effect L2 vocabulary recall.

Keywords—augmented reality, mnemonics, visuospatial bootstrapping, second-language learning, vocabulary retention

1 Introduction

1.1 Background

Vocabulary learning difficulties, although considered to be a norm in second-language (L2) acquisition, have always caused worries among learners, motivating researchers, teachers, and application designers to look for new ways to stimulate memory. To be able to communicate in a new language, it is recommended a learner obtain at least 2,000 items of high-frequency vocabulary [1]. This means that efficient visualisation techniques are crucial to retaining any meaningful amount of vocabulary. Vocabulary memorisation can be defined as the ability to "remember things after an interval of time. In language teaching, retention of what has been taught may depend

on the quality of teaching, the interest of the learners, or the meaningfulness of the materials" [2]. The most common techniques implemented in classroom vocabulary instruction until now rely on verbal (learning through context, definition, keywords, synonyms, antonyms, scales, word grouping) and visual aids (drawings, photos, common objects, physical response, schemes, semantic mapping). Flashcard-supported memorisation through repetition is easy to use in daily life [3], which influenced the method´s popularity. A word card (flashcard) was identified by Nation [4] as writing a word in a target language on the front part of a card (form) and providing its definition in the language of origin (meaning) on the back side. Modern flashcards can be translation-, image-, sound-, or animation-supported, among other options.

Traditional vocabulary instruction gave way to the contextual learning and application of mnemonics in L2 acquisition proposed by Schmitt and McCarthy [5], which was in turn followed by a search for new methods and experimental approaches to word memorisation. Technological and methodological progress also had an impact in this field through computer-assisted language learning (CALL) and its later subset of mobile-assisted language learning (MALL), which during the latter half of the 20th century and the start of the 21st century significantly transformed the way languages were taught [6], [7]. Since the advent of the Internet and mobile applications, self-study language-learning proprietary, freemium (i.e. freely available but with in-app purchases that grant certain advantages), and freeware applications have been developed and made available to the public, with Babbel [8], Busuu [9], and Duolingo [10] among the highest-ranking ones. Such self-instruction possibilities have made learning a new language more accessible and casual [11], [12].

The success of the Pokémon Go [13] mobile game—released in 2016 by Niantic, the developers of another augmented-reality mobile game called Ingress [14]—drew researchers' attention to the use of augmented reality in education [15] - [18]. Ingress' innovative use of game design relied on displaying virtual game characters among real-world objects by tracking the camera's position and orientation in relation to the environment. Augmented reality overlays a virtual environment on top of a projection of the real world, unlike virtual reality (VR), which projects a fully virtual environment that follows the movements of the observer [19]. Practical applications of AR can be found as early as 1957 in the cinema industry, and later during computer-graphics research and experiments with head-mounted displays. By 1980 a photographically overlaid reality was achieved on a portable-computer prototype [20] - [23]. The United States Air Force tested the system in the 1990s, obtaining positive results [24]. The educational possibilities of this technology have since been observed and explored for pre-school use in such applications as AR Flashcards [25] for alphabet and animal learning, Quiver Education [26] for colouring, and Narrator AR [27] for writing. Primary- and secondary-school applications include Amazing Space Journey [28] for astronomy use, Experience Real History [29] for history, Anatomy 3D Atlas [30] for natural science, biology and anatomy, and AR Critic [31] for foreign-language study and translations. Research has also been conducted on how AR can be used for 3D visual aids for books [32], as well as for teaching geometry [33] and science vocabulary [34]. A variety of sources describe the educational possibilities of AR, but there is still a lack

of research in this field, and more study is required to obtain enough evidence of its practical benefits [35].

Augmented reality is less immersive than virtual reality as it combines both real-world and virtual-world elements, but it also provides possibilities for integration into any familiar environment. Linking geographical locations to items which need to be remembered is called the method of loci. First applied by the ancient Greeks and Romans, it entails associating a word or image to an attribute on a layout of the environment so that one can recall this word or image through the association of the two. The mental map of the surroundings that is thus created supposedly aids recall, and research attests to the efficacy of the technique [36], [37]. There are parallels between the method of loci and AR technology: they both rely on visualisation, and since L2 acquisition requires large amounts of memorisation, the three could potentially be combined to create an AR language-learning application applying the method of loci to a flash card-like map of the user's familiar environment. Previous research shows that separately flashcards, the method of loci, and AR show positive results in the domain of education, so it is logical to assume that combining them can produce an effective tool. The MnemoRoom4U prototype was designed for mobile devices with the Android operation system (optionally iOS), thus providing a technologically accessible alternative to commercially available software such as Loci Memory Palace [38], developed by In Formation, Inc. for mixed-reality immersive head-sets. The experimental app is meant to be used for second-language vocabulary recall, but its use could be extended to other, educational and non-educational sectors that require the efficient memorisation of non-related items.

The research question of the study was: how can the implementation of MnemoRoom4U (the experimental technique) improve second-language vocabulary retention in comparison with conventional alternatives? The hypothesis of the study was that MnemoRoom4U offers a more motivating and immersive environment for L2 non-related vocabulary recall than traditional techniques. The aim was to provide a holistic picture of the use of the application and its alternatives based on users' experiences. Related research in psychology conducted by Darling, Allen, and Havelka [39] under the name of visuospatial bootstrapping revealed that it was more productive for recalling numbers to map them out on a keypad-like grid than to display them one by one in sequence or mapped out linearly. In other words, there is an advantage in memory retention when items are visually linked with spatial locations. A recent quantitative study in applied linguistics conducted by Larchen Costuchen et al. [40] showed that augmented-reality cards under visuospatial bootstrapping and taking a real and an imaginary route through various objects in participants' households helped to retain formulaic language (idioms) more efficiently than the conventional method of digital flashcards on devices. The AR-VSB method was significantly more efficient for second-language vocabulary learning than digital flashcards supported by image and translation after both 15 min and 1 week, despite a higher forgetting rate, which is promising for this research paper's hypothesis.

A number of sources [41] - [44] attest to the efficiency of a similar mnemonic technique, the method of loci, applied to different fields. This work proposed replacing imaginary elements with augmented-reality technology (virtual sticky notes) in foreign-

language vocabulary training and to bring to the foreground the holistic user-experience approach when dealing with the technological artefact MnemoRoom4U.

2 Method and application development

This proposal focuses on Design-Science Research (DSR), whose goal is pragmatic, aiming to design solutions to a problem [45], [46]. Specifically, this work follows a DSR subtype, Design-Inclusive Research (DIR), proposed by Horváth [47], which consists of three phases: (1) exploration of the problem, the context, and the activities; (2) design and testing of the solutions; (3) validation of the research. The application was developed in the Unity [48] game engine (Figure 1) with the ARCore [49] augmented-reality plug-in for Android. The necessary scripts were written in C# using Visual Studio (Figure 2), [50], which handled the creation of sticky notes in the app and the words that should appear on them using the existing Google sample scenes found in the ARCore Extensions package. Google Cloud [51] was used to create an API key that allowed cloud anchors to be hosted from the target device for up to one day. The application was built into an APK file for downloading and installing on any Android device that supports ARCore, or Google Play Services for AR [52] as it is known on Google Play (only a limited number do [53]).

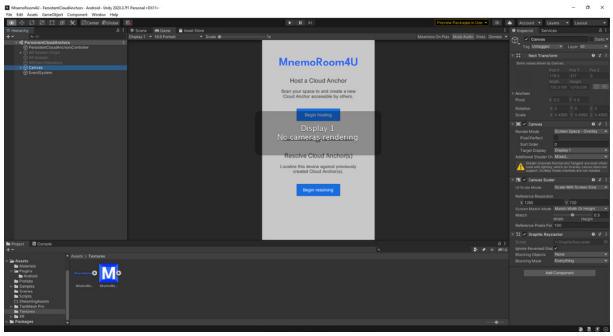

Fig. 1. Development environment – Unity

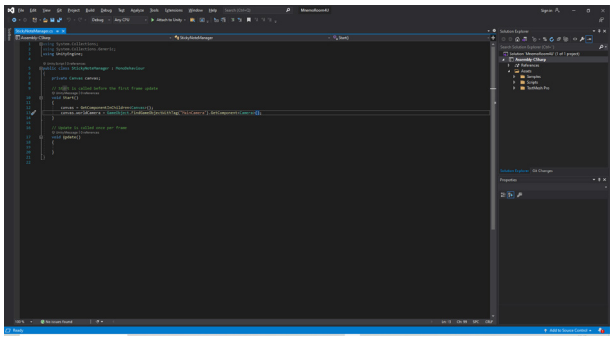

Fig. 2. Development environment – Visual studio

The conceptual design of the app consists of 5 steps: (1) the user distributes the L2-L1 words on the virtual sticky notes around the familiar environment (e.g. the user's home or office) close to the selected objects (e.g. entrance door, television, window, painting, etc.); (2) the user observes the spelling and translation of each item; (3) the user repeats the route as many times as necessary (moving always in the same direction and keeping in mind the order of the objects on the route); (4) the user does the post-test. The research population (N = 12) consisted of Spanish native or bilingual speakers who had no previous knowledge of Swedish. All the participants consented to participate in the study and were subsequently randomly distributed into three groups (one experimental and two control) with 4 participants in each (n = 4). One group was asked to use translation-based cards presented one by one, another group was instructed to use paper sticky notes combined with a route or routes around some familiar environment, and the experimental group used the application combined with a route or routes around some familiar space. The post-tests (immediate delay) were used to collect the scores; however, this study took a phenomenological perspective of lived experiences, relying for its analysis on field notes and semi-structured interviews. In all the groups, learners were not time-restricted during acquisition, but they were asked to check how long it took them to feel ready to do the post-tests. The current prototype did not use any deep-learning API, which is why the list of 15 non-related vocabulary items in Swedish (Table 1) had to be included into the programming stage.

Table 1. A list of words selected as L2

L2 (Swedish)	L1 (Spanish)	English (Translation)
Tangentbord	Teclado	keyboard
Penna	lapiz	pencil
handel	comercio	commerce
Högtalare	Altavoz	speaker
Dom	Juicio	trial
Ansluta	conectar	connect
Skön	Bonito	beautiful
Förstöra	Destruir	destroy
Svår	Dificil	difficult
Tak	Techo	roof
Väska	Bolso	bag
kunskap	conocimiento	knowledge
Väg	carretera	road
Tvivel	Duda	doubt
flygplan	Avion	airplane

The post-test design for immediate delay used an orthographic structure. The post-tests (Table 2 and Table 3) were presented sequentially, not simultaneously.

Table 2. Post-test 1

Post-test 1: choose the correct letter among the three options		
tan*entbord (k, j, g)	kuns*ap (h, j, k)	hand*l (e, a, i)
hög*alare (t, d, i)	t*ivel (w, v, y)	do* (n, m, r)
*nsluta (e, a, u)	väs*a (c, h, k)	sk*n (o, ö, n)
för*töra (s, z, c)	*enna (r, p, t)	*vår (z, f, s)
*ak (l, t, i)	v*g (ö, u, ä)	fl*gplan (o, y, a)

Table 3. Post-test 2

Post-test 2: choose the L2 equivalent among the three options				
Lapis a. penna b. tena c. henna	Bolso a. wäska b. väska c. väkka	Altavoz a. högtalare b. högtalere c. gögtalare	Conectar a. ansluta b. alzluta c. anslata	Techo a. taf b. tuk c. tak
Bonito a. sfön b. skön c. sken	Teclado a. tangentbort b. tangentbord c. fangenbord	Juicio a. tom b. dom c. don	Duda a. dvivel b. tvivel c. tviwel	Avion a. flugplan b. flygplan c. fligplan
Comercio a. handell b. jandel c. handel	Carretera a. wäg b. väh c. väg	Destruir a. törstöra b. förstöra c. förstöry	Conocimiento a. kunskap b. hunskap c. kunzkap	Dificil a. svår b. svus c. sver

The pedagogical approach for method evaluation used a 3W3H model integrated with the DIR. It was guided by the following questions: (1) Who are the method users? (2) What vocabulary items are used for recall? (3) How is the method used? (4) Why is the method efficient? (5) How did the participants feel? (6) How can the method be improved?

3 Results

The 3W3H model was applied to collect data on the participants' experiences and opinions in relation with the experimental and the control techniques.

3.1 Participants and input

The participants were all Spanish C2 speakers (native or bilingual); graduates of the Polytechnic University of Valencia (UPV) or University of Valencia (UV); holders of a Master´s, Postgraduate, or PhD degree; and active users of mobile phones and computers, with 91.6% belonging to the "digital native" category as defined by Prensky [53], according to whom "children raised with the computer think differently from the rest of us. They develop hypertext minds". The participants´ ages ranged from 26 to 48, with all but one of them having been born in the digital era. None had any prior knowledge of Swedish, but all spoke other L2s at different levels. The L2 lexis was

composed of non-related items in Swedish selected randomly and checked for possible similarities with the participants' L1 (Spanish) to avoid interference.

3.2 Experimental group

In the experimental group, MnemoRoom4U was combined with one or several routes around a familiar environment (Figure 3). L2 and L1 were presented on the same side of the virtual cards. The system required the use of a compatible mobile phone [54]. The task consisted of carefully looking at the L2-L1 virtual notes distributed on or beside the objects in the household or office while walking through the route or routes (time-limited: no; time-controlled: yes; post-tests: immediate delay). Innovative elements presented in this work include the use of AR instead of imagery elements and the use of AR instead of paper-based or digitally presented notes with textual information. This study collected information on the motivational factors related to this method, on how the participants felt, and on how this method/application can be improved according to users' opinions.

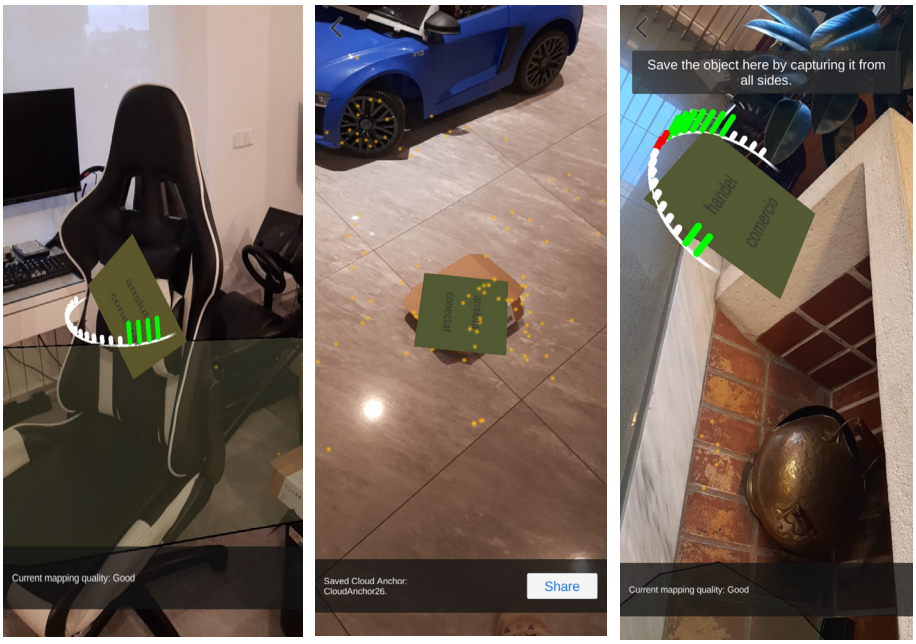

Fig. 3. Virtual sticky notes placed beside an object in a household

Table 4 summarises the post-test scores (maximum score = 29), the time required (in minutes) to set up the environment and to recall the items, the Likert scale on motivation (1 = very boring, 7 = very entertaining), and the Likert scale on the application's design (1 = very difficult to use, 7 = very easy to use).

Table 4. Experimental group

	Participant EG-1	**Participant EG-2**	**Participant EG-3**	**Participant EG-4**
Post-test score	28	29	28	27
Time	32	28	23	40
Motivation	7	7	7	6
Design	7	7	7	6

Participant EG-1. "The easiest words to memorise were *tvivel* (I remembered that the first letter was *t*) and *tak* (probably because it's short). I thought about Taco Bell at that moment. The most difficult words for me were those that contained *ä* and *ö*. In one part of the test, I had to choose between *sfön*, *skön* and *sken*. I was sure that it was not the last one, but I had a doubt between the previous two. There was a curious thing with the word *förstöra*. When I saw it, I thought that it was the most difficult of all because it contained two *ö*. In the end, it was the word that I best remembered." "I used it in my house, it worked best with medium-size furniture pieces or objects (preferably on the floor or walls). I am sure I would use it faster next time. The objects that are a bit far (on the ceiling) generated a smaller card. It should be kept in mind." Improvement tips: "Some cards looked reverse, but it was ok. The text was clear to read."

Participant EG-2. "The words would not be too difficult to remember. I had to use them for speaking, but I tried hard to recall the spelling and that was pretty challenging." "I would call it some fairy-tale-like experience. It was great fun. Never tried such a system before. I would be happy to use this or a similar app to improve my French. The easiest word to memorise for me was *skön*. I associated it with a name of a small cute white dog. It still sounds like a name to me. Probably another association was with the word *guapo – cute*." Improvement tips: "I would appreciate some video on how to use the application. The ReadMe document was clear and well written, but I am a very visual learner. I prefer videos and pictures."

Participant EG-3. "Associating foreign words with the objects was a curious thing. It was weird, but it worked." "The easiest word to memorise was dom. I memorised it as mod read backwards. The object to host was a VRAM box. I associate the word *väg* with *vago* in Spanish and vague in English. I imagined somebody who was lying on the sofa and did not want to go on a business trip. He did not feel like driving that day. The object that I used to host that anchor was my backpack on the floor, not far from the sofa." "I liked the colour of the cards (green) and the system of lights that appeared when you scanned the objects. It was also quite intuitive to observe red, yellow, and green indicators of the correct scanning of an object." "I think such an app would be useful to memorise passwords (e.g. strong bitcoin wallet password)." Improvement tips: "Probably I would enjoy it even more if the application had a pronunciation option and an image option too. However, I understand that not all the words can be presented as an image, especially when it comes to some abstract terms."

Participant EG-4. "The easiest words to memorise were *tak* (association with a word in Ukrainian that sounds the same and means *yes*, *so*) and *dom* (association with a Russian word that sounds the same and means *home*). I associated the word *ansluta* with connect not only because of the translation but also because the reference object

in the household was an electric water boiler with a cable." "The objects around the house helped me to recall the words in the following order (e.g.: the frog – *kunskap*, the ball – *tvivel*, the painting of a house – the word *destruir* in Spanish, the plant – *lapiz - penna*). First I recall the object, then the word in Spanish and only then the word in Swedish." "Sometimes I couldn´t remember the last element, the word in Swedish." Improvement tips: "It takes some time to get accustomed to the application and to scanning the objects. The application provides a beautiful blend between real and virtual elements, but you should keep in mind the safety measures when you move around your household scanning the objects."

3.3 Control Method 1

Translation-based, L2-L1 word cards were presented to the participants one by one in random order (Figure 4). L2 and L1 were introduced on the same side of the cards, which could be either printed out or presented virtually on a mobile-phone device. The task consisted of carefully looking at the L2-L1 notes (time-limited: no; time-controlled: yes; post-tests: immediate delay).

Fig. 4. L2-L1 word card on a digital device

Table 5 summarises the post-test scores (out of 29) and the time required (in minutes) to train recall. Seven-point Likert scales were used to measure user's motivation (1 = very boring, 7 = very entertaining) and their evaluation of the application's design (1 = very difficult to use, 7 = very easy to use). The cards were prepared by a peer—a friend or family member who needed from 5 to 10 minutes to prepare the activity (not included in the table).

Table 5. Control method 1

	Participant CG1-1	**Participant CG1-2**	**Participant CG1-3**	**Participant CG1-4**
Post-test score	26	26	29	29
Time	15	10	10	12
Motivation	1	3	1	4
Design	7	7	2	6

Participant CG1-1. "The easiest words to remember for me were *penna* (association with *pen* in English), *dom* (association with *doomed* which means *ill-fated* or

condemned in English), *tak* (association with *tall* in English and with a word combination *tall/high roof*). *Skön* (association with Ikea furniture). The technique that I sometimes use to memorise unrelated information, or a list of new vocabulary is writing that list down a lot of times (by hand). Another option is writing short notes or making some scheme or a drawing. Such things work quite all right for me. The second part of the test was easier for me than the first one. I thought I remembered the word, but then I could not remember what the missing letter was." Improvement tips: "Probably the same card system could be used on mobile phones with the option of note writing, drawing making, and pronunciation recognition." "For note writing, mobile phones like Samsung Note are really handy."

Participant CG1-2. "Easiest words to memorise were *handel* (association with *hand* in English and *del* in Spanish; I thought about a person with coins in his hand). I associated the word *dvivel* with the Spanish imperative *vive – live* in English and *doubt*, like *live with a doubt, dvivel*." "I used paper flashcards in the past. The great thing is to pass them from one pocket to another (one pocket for those words that you have already learnt, and the rest go to another pocket). I also know that there are apps for mobile phones which use the same system with sound / pronunciation." Improvement tips: "A visually attractive app would be better than just looking at white paper with some text."

Participant CG1-3. "The easiest words to memorise were *penna* (association with *pencil* in English), *tangentbord* (association with *board* in English), *flygplan* (association with *fly* and *airplane* in English). Two words looked a bit similar, *skön* and *svår*, which made it difficult for me." "I don't like this method for vocabulary memorisation." Improvement tips: "Well, I guess that the foreign-language words could be linked to images. The learner would need to listen to pronunciation several times and look at the image at the same time." "Probably some contextual use of a new work would be a necessary element, something similar to a dictionary text but on a separate card."

Participant CG1-4. "All the words were easy to memorise except for *dom*, *kunskap*, and *väska* because they are not similar to their equivalents in the languages I know." "The associations that I had were the following: *Tangentbord – teclado*, *keyboard* and *board* in English. *Skön – bonito – schoon* in Flemish. *Väg – carretera – weg* in Flemish, *way* in English, *Weg* in German. *Penna – lapis* – You write with a pen. *Förstöra – destruir* – sufficiently similar in meaning to *verstoren* in Flemish. *Tvivel – duda* – this one confused me a bit at first because it made me think of *duivel* in Flemish, which means *devil*. But then I saw *twijfel* in Flemish, which is *duda*, *doubt*. *Handel – comercio* – Exactly the same in Flemish, *handel*. *Svår – dificil* – Schwer in German, *zwaar* in Flemish. *Flygplan* – avion – *Flyg* is very transparent, but I was confused because I thought of *flight plan*. Then I associated plan with airplane. Improvement tips: "When the participants have to choose between three options, make it easy on them to indicate their choice."

3.4 Control method 2

Paper sticky notes were combined with one or more routes around a familiar environment. Materials could be printed or hand-written. When hand-written, the sticky notes had to be prepared by a peer, i.e. a friend or family member with clear handwriting

(Figure 5). L2 and L1 were introduced on the same side of the cards. The task consisted of carefully looking at the L2-L1 notes distributed on or beside the objects in the household or office during the route or routes (time-limited: no; time-controlled: yes; post-tests: immediate delay).

Fig. 5. A paper sticky note placed beside an object in a household

Table 6 summarises the post-test scores (out of 29), time required (in minutes) to train recall, the Likert scale on motivation (1 = very boring, 7 = very entertaining) and the Liker scale on application design (1 = very difficult to use, 7 = very easy to use). This activity was peer-assisted, which required from 5 to 7 minutes of additional time to prepare the environment (not included in the table).

Table 6. Control method 2

	Participant CG2-1	**Participant CG2-2**	**Participant CG2-3**	**Participant CG2-4**
Post-test score	28	24	28	29
Time	20	5	17	18
Motivation	4	6	4	5
Design	6	6	5	7

Participant CG2-1. "The easiest words to recall were *penna* (association with pen in English), *svår* – association with *schwer* in German and *flygplan* - association with *Flughafen* in German." "The system of distributing sticky notes around my house was unusual and I had to understand how and why it worked. It did. It was neither very entertaining nor uninteresting, it was all right." Improvement tips: "Probably in the near

future gadgets will provide much more data to us about anything in the physical world (scanning for information about anything around you)."

Participant CG2-2. "I was guided by the root of words like: *penna*, *flygplan*, *tangentbord*, one letter substitution like: *skön (schön), väg (weg),* multiple letter substitution: *tak, ansluta* and some faraway relation (e.g.: *dom* in German is *cathedral* but in Swedish - *juicio*)." "Associations: *penna* - *pen* (English), *skön – schön* (German), *ansluta* - *anschliessen* (German), *tangentbord* - *keyboard* (English), *wäg* - *weg* (German), *tvivel* - *zweifel* (or something similar) *förstöra* - *zerstören* (German), *kunskap* - *kenntnis* (German), *tak* - *dach* (German), *flygplan* - *flugzeug* (German), *sver* - *schwer* (German)." Improvement tips: "Learning a new language is always tough at the beginning, so different techniques can help people and motivate them." "To memorise unrelated vocabulary items I normally use flashcards, write down words that I heard during the day together with the situation."

Participant CG2-3. "A difficult word was *väg*. In a test I chose *wag*. I had an association with a Volkswagen car, and I was not sure if it was correct to write *Wolksvagen* or *Volkswagen*. It was very confusing. The sticky note with a word was placed on my aircon." "At first I thought that such a system would be great if you used the sticker to indicate what the real object meant (for example, let's take the gas stove and translate this word into a couple of other languages. Then I thought that we cannot put a sticker on everything, and there are more complex concepts that require specific translation." "It was my first experience with the mind-palace system. I could try to use it to remember speeches that I have to prepare in English). One of the easiest words to remember was *väska* (I remembered the part *ska* and I imagined a black handbag with a big golden *V* letter). The word *kunskap* was also relatively easy. I associated it with *kunst*, which means *art*. I never studied German, but somehow I know the word." Improvement tips: "This system could be more interesting if we could use some technology (probably some voice assistant and a writing assistant; all - on an electronic device)."

Participant CG2-4. "The shortest words with no special symbols were the easiest." "I just used the instructions and was trying hard to memorise. What helped me to learn was the order of the words and the objects. It was really helpful. This system made me feel more relaxed than when you try to memorise for example a shopping list not in a given order." Improvement tips: "I just thought of a room with empty walls that could be filled with any learning content (by projections, for example)."

4 Discussion

The Likert-scale findings demonstrate that the use of the experimental technique was significantly more appealing and motivating to participants than the control methods. However, it took the learners more time to set up the environment and to do the training. The application produced a positive effect on the users, with all of them finding it intuitive and quite easy to deal with. The important general takeaway from this study is that the majority of the participants used associations based on the similarities between the unknown words and the languages they had some knowledge of. Moreover, some participants in the experimental groups in Control Method Two linked objects with the

chains of associations, which is another interesting issue for further research and updates of MnemoRoom4U. The control groups' participants mentioned the possibility of adding personalised images and pronunciation options, which will be included in new MnemoRoom4U versions. All the participants performed quite well in the post-tests, although due to the nature of the qualitative study we cannot make any conclusions based on numerical information and comparison between the groups. More research (qualitative and quantitative) will be required to test the updated MnemoRoom4U versions that may contain a wider range of possibilities (API for Indo-European languages, personalised images or doodles, hearing and reproducing pronunciation). All these elements provide additional technology-related challenges at the programming and testing stages.

5 Conclusion

Combining AR technology with mnemonics and language didactics was an exciting goal, however developing the current application was not an easy task for the author and the developer, as it required interfacing with Google Cloud's very unwieldy API. Creating an API key that supported cloud anchors that could be hosted for up to one day was feasible but hosting them for a longer period of time (up to 365 days) required maintaining the locations of all the loci, and an OAuth 2.0 client ID was needed [55]. After trying to get it working for several weeks, the effort was abandoned in favour of the simpler API-key method. Due to the aforementioned issues, the rest of the application was developed for experiments to be conducted within a 24-hour time period. Future versions of the application will foreseeably feature other AR frameworks as well as more and richer data. Since context-based learning in AR is another highly promising emerging pedagogy, its elements are planned to be added to MnemoRoom4U as an alternative to mnemonics. We hope to expand this research with more analysis of digital and non-digital generations in second-language vocabulary recall (applied to a variety of latin-based languages), and to consequently verify if there may be any statistically significant differences in performance between genders. We hope to contribute to innovations in education, in teaching languages, and in lexis memorisation, and finally to make vocabulary recall more fun.

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