Memorization techniques: a literature review to verify the feasibility of implementing memorization techniques through tangible user interfaces

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Abstract. This work wishes to present some studies existing in the literature that refer to memorization techniques. After a short introduction, where cognitive processes involved in memory and learning (perception, attention, codification, and recovery) will be mentioned, we will proceed to an analysis of the scientific contributions that represent the scientific substratum of mnemonics. In particular, this work will consider existing studies that focus on the efficacy of the mnemonics "keyword method" in the study of foreign languages, which represent the vast majority of the studies currently existing in the literature. The purpose of this review is to identify possible memorization techniques and verify if, in the future, it will be possible to use these techniques by developing technological tools based on tangible user interfaces.

Keywords: mnemonics; keyword method; foreign language teaching.

1 Introduction

Memory is defined as a cognitive function, which is primarily focused on the storage and retrieval of information: this information is elaborated, archived, and retrieved when necessary [1]. As soon as the information gets perceived [2], it transits into the working memory, or short-term memory, and gets screened to access the long-term memory, namely, the "archive" where all the information gets stored and retrieved when needed. Short-term memory is very limited as it can store a maximum of seven items [3] for a handful of seconds, and it needs to correlate new pieces of information with the ones already stored in the long term memory, which has unlimited capacity, and where it's content remains almost permanently [4]. Mnemonics have been an object of interest and study since ancient times. Just think about all the sections dedicated to it in great works such as the "De oratore or Rhetorica ad Herennium". With the term mnemonics, we refer to a group of rules and strategies that ensure the memorization of information and, through the creation of associative links, increased memory capacity [5]. Mnemotechnic represents a powerful pedagogical tool. It is accessible and easy, it favors the creation of associations through the use of a vivid

imagination that imprints the item in the memory, and transforms the learning process in a cognitively and emotionally stimulating activity [6, 7]. There are multiple memorization techniques. For example, some authors suggest training memory by using images, images, and rhymes, creating personal memorable associations, dividing words into significant parts, combining sentences to write or inventing stories [8]. Some Russian scholars suggest the use of “mnemotables", which are schemes drawn with determined information, together with the following methods: "chain" (linking images in associations); symbolization (to memorize abstract concepts); tie concepts to familiar information to facilitate engagement [7]. Furthermore, it is appropriate to mention the technique of loci: the transformation of concepts, information, into mental images with the consequent positioning of these in places. This technique requires that the mental images created are clear and precise, in such a way as to always allow double encoding, that is, as we have viewed the image from the term (Encoding or Viewing Phase), it will be possible, having seen the image, to trace the information to remember (Decoding or Verbalization Phase); the P.A.V. (Paradox, Action, Vivid), a technique that allows you to associate a paradox with a certain element, transforming this element into an action. Using this tool, it is possible to provoke a vivid emotion in the subconscious that produces a mental connection capable of activating the ability to memorize. The technique of phonetic conversion, a technique of memorizing numbers. It works by converting numbers into consonants and, by appropriately adding vowels, transforming them into words that can be remembered more easily than a series of numbers, particularly using other mnemonic rules (P.A.V. and loci technique). Finally, we have the " Keyword method " (Atkinson) which is the most used memory technique in the study of foreign languages.

2 Literature Analysis

Studies in the literature have placed their focus on the use of memory techniques in relation to the study of foreign languages. Specifically, the "Keyword Method" turns out to be the memory technique that most represents the object of study in relation to the effectiveness of memory techniques. The term "Keyword" was used by Atkinson in 1975 in an article where he proposed the use of this type of mnemonics to facilitate the learning of the vocabulary of foreign languages. Within the article, Atkinson analyzed the effectiveness of the "Keyword" technique for the study of the Russian language for English-speaking subjects. This mnemotechnic is based on two phases, verbal and visual. The first phase consists of developing a keyword that is concrete and that is as similar as possible from the phonetic and spelling point of view to the word you want to memorize. The second phase consists of constructing an image that associates, relates the previously elaborated keyword with the meaning of the word under consideration[9–11]. Following the description of this mnemotechnic, several studies have been carried out in order to corroborate its effectiveness[12–15]. The keyword mnemotechnic results effectively in laboratory situations, when applied individually and when the keyword is provided by the experimenter. However, the

results of the above studies are not equally clear when referring to the application of this memory technique in a collective context, such as the classroom [16, 17] and, similarly, in natural contexts, without control over the environment, where the subject elaborates the keyword [11, 18, 19], or in group situations [20]. Furthermore, Campos [11], highlights a further limitation of this mnemonics in reference to the moment of memory.

According to the author, the mnemonics of the keyword are effective in reference to a short-term, immediate recall of information; on the other hand, it would be less effective if we refer to a long-term recall of information. In accordance with what was previously stated, some studies in the literature [18, 19, 21–23] do not show any positive effects in the use of keyword mnemonics for long-term memorization. However, other studies carried out by Mastropieri, Emerich, and Scruggs [21]; Merry [24]; Sweeney and Bellezza [25], record the effectiveness of this mnemonics also in the long term. Subsequently, with the aim of improving some of the criticalities listed so far in the "keyword" memorization technique, Campos and colleagues [26] carried out experiments that consisted of greater processing of the "keyword"; specifically, they carried out a study with students aged 12 to 15 (Educación Secundaria Obligatoria), who had the task of learning the meaning of a list of 30 Latin words using the mnemonics of the "key-word" in a different way: a group had to autonomously elaborate its own keyword, another group benefited from the experimenter's help in choosing the "Keyword" and the third group was given a "keyword" that had previously been chosen and elaborated by the companions of the experimental group. The group that used the "keyword" developed by the peers memorized the word list both immediately and after a week significantly more effective than the other groups. In another study by Campos [26] carried out two experiments to evaluate the effectiveness of the "keyword" mnemonics. In the first experiment, they used 4 groups of subjects aged 12 to 15 (Educación Secundaria Obligatoria) who were given a list of 16 Latin words, the first 8 with images, and the last 8 without images, that had to be memorized using different strategies. One group had to learn the wordlist through the method of repetition, the second group through the mnemonics of the "Key Word" generated independently, the third group instead, used a keyword provided by the experimenter and the fourth group used a keyword generated and elaborated by the companions of the experimental group. The most important result obtained from this study was that the words with vivid images, the group that used the “keyword” mnemonics, remembered more significantly than the group that used the repetition method. In the second experiment, they administered a list of 32 words and verified that with words with images, the group that used the keyword elaborated by the companions, produced a more effective memory than both the group that used the method of repetition and the group that independently elaborated their own keyword. Furthermore, in relation to the studies on the efficiency of "keyword" mnemonics in the study of foreign languages, Shcherbakova, O., Cherkashina, T., Yakhno, M., Budanova, I., & Galoyan [5] state that the use of mnemonics in the classroom guarantees the systematic and conscious acquisition of the material under study, contributing to the rapid understanding of the specific rules of the target language. Transforming didactic material into visual images or

comparing it with the knowledge already acquired on the basis of the association principle, guarantees its memorization and arouses interest in the lesson. The studies carried out to verify the effectiveness of the "keyword" mnemonics were mostly carried out with children, adolescents, and university students, consequently, it was necessary to produce scientific works in order to verify the actual effectiveness of this mnemotechnics also in relation to adults. Therefore, some studies present in the literature [27, 28], affirm that the vividness of the image elaborated by adults, necessary to implement mnemonics, turns out to be lower than the one elaborated by younger subjects when used as a measurement in a performance test. However, when questionnaires are used, there are no significant differences between the different age groups [26, 29, 30].With regards to the results of the few studies in the literature on the effectiveness of the use of "keyword" mnemonics with adult subjects, some scholars support the use of the "keyword" strategy [14, 31, 32] others, on the other hand, affirm that there is no increase in memory through the use of this mnemonics [33, 34]. However, in summary, it is possible to state that adults can also benefit from mnemotechnic even if with lesser effects than young people and with the need for more training [35–38]. Later, Campos and colleagues [39] carried out a study to verify the effectiveness of mnemonics for the study of the Latin language with adults. Participants used interactive images to impress memory since processing interacting images turns out to be the most effective form of using mental images [10, 40]. The group of people who participated in the experiment had an average age of 59.35 and had to memorize the translation of a list of 16 Latin words. The group that used the "keyword" mnemonics recorded a significantly more effective memory, both immediately and after one day, than the group that used the repetition technique. In the second experiment, the experimenters used a list of 24 words, of which the experimented subjects had to learn the translation using the “keyword” mnemonics with the addition of drawings/images. In this case, too, a significantly more effective memory was recorded than the memory of the group that used the repetition technique.

Table 1. Studies list

Authors	Design and purpose	Participants	Outcomes
Atkinson (1975)	use of this type of mnemonics to facilitate the learning of the vocabulary of foreign languages		1.keyword method produces significantly great vocabulary recall than the rote rehearsal method of second-language learning.
Campos et al. (1993) “Sex and age differences in visual imagery vividness.”	Evaluated sex and age differences of responses on the Vividness of Visual Imagery Questionnaire.	155 females and 134 males in 3 age groups (14–20 yrs., 21–40 yrs., and 41–60 yrs.)	visual imagery vividness is significantly influenced by sex, but age by itself and the cross-term had no

			significant effects.
Alfredo Campos, Maria Josè Perez, Maria Angeles Gonzales (1997) "The Interactiveness of Paired Images is Affected by Image Bizarreness and Image Vividness"	investigate the extent to which 1) the types of images generated by the subject (normal or bizarre), 2) the vividness of the images generated, and 3) the subject's imaging ability affect the degree of interaction between images	152 Spanish compulsory secondary education students	The results were essentially the same regardless of whether words were presented in short (16-pair) or long (32-pair) lists.
Campos et al. (2003) "Limitation of the mnemonic keyword method"	The effectiveness of the mnemonic keyword method was investigated in 4 experiments.	Experiments 1 (adolescents) and 2 (adults). Experiments 3 (adolescents) and 4 (adults).	In all experiments, the rote method was significantly more effective than was the keyword method.
Campos et al. (2004) "The Importance of the Keyword-Generation Method in Keyword Mnemonics"	In this study, two experiments were performed to assess the efficacy of a new keyword-generation procedure (peer generation)	363 high-school students were randomly divided into four groups.	the peer-generated keyword group showed significantly better recall of high-vividness words than the rote method groups and the subject generated keyword group.
Campos et al. (2007) "Mental imagery, recall and recognition in high vivid imagery subjects"	The effects of different image types: normal, bizarre, or mixed imagery on immediate, after a day, and one week, in high vivid imagery subjects were investigated.	175 Spanish Secondary Compulsory Education students (90 men and 85 women)	the influence of image type on short-term memory, and revealed that recall performance was greater with mixed imagery that with bizarre or normal imagery strategy.
Campos et al. (2010). "Efficacy of the keyword mnemonic method in adults".	Two experiments were used to assess the efficacy of the keyword mnemonic method in adults	A group of adults. The mean age of the sample under study was 59.35 years	Immediate and delayed recall were significantly greater in the keyword mnemonic method group than in the repetition method group

Culpaper et al. (1998) "Using mnemonic keywords in general music Classes: music history meets cognitive psychology"	Students from two sixth-grade classes received instruction in music history regarding composers and the musical periods in which they worked in a counterbalanced design over a 2-week period.	45 students who participated in this study were enrolled in the sixth grade in a suburban school in the Midwest.	Students scored statistically and substantially higher on recall tests involving items presented with mnemonic illustrations.
Gonzalez & Amor (2004) "different strategies for keyword generation"	This study tested the efficacy of keywords previously generated by subjects of similar sociodemographic characteristics.	284 Spanish high school students, aged 12-16 years.	The result indicates that both immediate and one-week recall was significantly better in peer-generated-keyword group than in the subject-generated-keyword and the experiment-supplied-keyword group.
Scailquin Jean-Christophe (2000) "Effects of Aging on the Generation of Mental Images"	In the present study, 165 healthy participants aged 18 to 80 years were enrolled for an image generation task to image an uppercase letter in response to its lowercase version displayed as the cue, and to decide if a displayed probe would be near to or on the image.	165 healthy participants aged 18 to 80 years	Comparative analyses (ANOVAs) on accuracy and correct latency confirmed the sequential nature of image generation, and showed a detrimental and linear effect of aging only on the activation subprocess.
Wyra et al. (2007) "The mnemonic keyword method: The effects of bidirectional retrieval training and of ability to image on foreign language vocabulary recall"	This study examines the effects on recall of word-meaning pairs of (a) training in the use of the keyword procedure at the time of retrieval; and (b) the influence of the self-rated ability to image.	36 female and 41 male Year 6/7 students (age 11e12 years)	The retrieval training was a significant predictor of both backward and forward recall performance, as was the ability to make images.

3 Discussion

The intent of this work is to verify the effectiveness of the use of mnemonics on the basis of the studies present in the literature. In relation to the abovementioned studies,

it is possible to insert the results obtained from the studies cited within the theoretical framework of Paivio [41–43]; who states that effective learning is coded through two systems, the verbal and the mental images. When we use the mnemonics of the keyword we produce a more effective memory from the moment we use both the verbal system and the mental images, while the method of repetition uses only the verbal system. However, Campos et al. [39] recorded a faster loss of memory in the subjects who used the "keyword" mnemonics compared to the group of participants who used the repetition method. This result, according to the authors, can be interpreted in relation to the theory of episodic memory of Tulving, which states that episodic memory is characterized by a good immediate memory but by a rapid decline of the same [44–46].

4 Conclusion

It is also appropriate to notice the lack of studies in the literature that set their argumentative focus on other memorization strategies. Furthermore, it would be relevant to highlight the opportunity to expand the studies on the subject in relation to the use of mnemonics as a compensatory teaching tool in learning disabilities (L.D.) and special needs students, in order to produce new techniques and teaching tools that can compensate for some difficulties present in these students [2]. Finally, it would be interesting to produce scientific works that could highlight the usefulness of the use of mnemonics, especially in the school / academic environment, in synchrony with the advancement of technology. Studies in the literature demonstrate the possibility of using technology to support the study of foreign languages based on keyword mnemonics. Manolis Savva presented TransPhoner: a system that generates keywords for a variety of scenarios including vocabulary learning, phonetic transliteration, and creative wordplays. In this work, the authors select effective keywords by considering phonetic, orthographic, and semantic word similarity, and word concept imageability. The result of this study shows that keywords provided by TransPhoner improve learner performance in an online vocabulary learning study, with the improvement being more pronounced for harder words. Participants rated TransPhoner keywords as more helpful than a random keyword baseline, and almost as helpful as manually selected keywords. Comments also indicated higher engagement in the learning task, and more desire to continue learning. The study demonstrates additional applications to tasks such as pure phonetic transliteration, generation of mnemonics for complex vocabulary, and topic-based transformation of song lyrics [47]. Another work provided by Anonthanasap et al. proposed a new educational system for second-language vocabulary learning based on a mnemonic technique. The system is equipped with the dynamic and interactive interface that allows vocabulary learners to seamlessly browse a collection of foreign words while suggesting phonetically related words of a known language for helping the memorization of unfamiliar languages. The phonetic algorithm is employed to encode the pronunciation of words. The phonetic codes of words are then applied to homonyms of different languages. The

Levenshtein distance is used to quantify the similarity of phonetic codes or of words' pronunciation. The mnemonic words with their associated images are presented surrounding the learning words according to the edit distance or phonetic similarity. With visual effects based on the user's input, the dynamic and interactive interface will help users browse a collection of vocabulary [48]. Furthermore, the creation of software that, through the use of Tangible User Interfaces (TUI), can exploit the attractive dimension together with the theoretical efficiency of mnemonics. For example, it might be interesting to use tangible interfaces such as cards with images, letters, or numbers connected to a software, to implement the storage of concepts, historical dates, scientific formulas. Using the theoretical model of keyword mnemotechnics. Specifically, in accordance with the recent evidence of the scientific literature and using the memorization techniques that have been analyzed in this review, we could identify innovative and multimodal systems useful for creating a learning support for students with SEN (Special Educational Needs) and SLD (Specific Learning Disorder).

5 Future direction

Future studies could exploit the potential of tangible interfaces and digital systems, implementing memorization techniques. In particular, the student's executive-attentional processes could be analyzed by designing psychological tests, based on tangible interfaces, useful for tracing analysis of the user's functional profile. The technological prototypes that could be created would exploit the attractive qualities of Game-based assessment and, in addition, the accuracy of an ecological assessment protocol based on tangible interfaces.

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