# Digital serious game based aid program for verbal memory training

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## Abstract

Many research data show that the phonological loop of working memory plays an important role in the process of learning new words (Baddeley et al., 1998). The aim of this study was to investigate whether the training of phonological loop has potential beneficial effects on the ability to learn new words. We developed a software program, which through the use of digital implementation aimed to strengthen phonological loop of working memory of the 27 young adults that participated. The application used here, took the form of a pleasant escape game, where participants practiced their immediate verbal memory (phonological loop) by recalling series of numbers. The application followed the typical features of such applications and the scenario of the game placed the player in the role of a burglar who tries to escape from rooms, by memorizing series of numbers. This article presents the evaluation results concerning the usefulness, ease of use, ease of learning, and the users' satisfaction of the application. The results in each category are positive.

Keywords: verbal working memory training, recall of series of numbers, game based learning

## Introduction

Working memory is a mental system that plays an important role in the completion of complex cognitive processes such as reading, vocabulary acquisition and mental arithmetic. The working memory retains and processes over short period of time information relating to work on progress (Mann & Lieberman, 1984; Miyake & Shah, 1999; Yuill, Oakhill & Parkin, 1989). According to a model of working memory proposed by Baddeley and Hitch (1974) the working memory comprises of three sub-systems: the phonological loop, the visuospatial sketchpad and the central executive. The phonological loop is responsible for the short retention of verbal and auditory information. The visuospatial sketchpad specializes in short retention of visuospatial and kinesthetic information, -for instance information relating to both the shape or color and the position or sequence of movements in space (Baddeley, 2003). The central executive is responsible for controlling attention and determines what information enters the two subsystems to be further processed. Its role is important in the coordination of the two subsystems, the phonological loop and visuospatial scratch pad, to allow simultaneous processing of visual and verbal information in both subsystems. It seems that one of the subsystems of the working memory (the phonological loop) is closely linked to the acquisition of language. Because the role of phonological loop is to hold the phonological structures of new words and to support their transfer to long-term memory, it is expected to involve in the learning of a language. Much empirical evidence shows that its contribution is decisive in the acquisition of new words in native and in a foreign language (Thorn & Gathercole, 1999).

The success of electronic games is the importance of fun and achievement of the immersion of the user, the existence of rules, aim, interaction with possibility of feedback and rewards within a story as stated by Prensky (2001). Furthermore, the existence of adjustment time in the game and the interaction between the players contributed to create teams and competition. Earlier, Cudworth (1996) pointed out that education must have, in addition to the aforementioned items, educational games need to have goals and take for granted the existing knowledge of the user. On the other hand, on their categorization Alessi and Trollip (2001) added the imagination, equipment, and safety directives.

The use of electronic serious games has many advantages and disadvantages for supporting training as mentioned by Count (2004) and Hickmott (2006). The main advantage is the development of learning and physical skills. Games can also contribute to problem solving and short or long term memory training. They encourage interpersonal relationships through cooperation or competition, as well as by the undertaking of roles to develop behaviors. There is the possibility of completion of activities, weak or costly in real conditions within a secure environment that can promote self-esteem of the users. In addition, a strategic development and management of several variables is offered. On the other hand, there is a risk of self-esteem reduction, aggression development aid loneliness and distraction from learning. People with copying behaviors can lead to difficulty of distinguishing reality and the virtual world, while careless use can cause significant symptoms to all. In case of absence of pre-existing skill its aid is not possible. Moreover, there has been correlation to specific ideological characteristics as sexist or racist views or obesity phenomena. It is also supported that time spent on insignificant activities such as learning and instruction how to use the game.

The purpose of this paper is the presentation of the design, implementation and usability evaluation of a software application for supporting the training of phonological loop, the verbal component of working memory (Baddeley, 1986) of a group of university students. Additional aim is the presentation of the preliminary findings on the effects on the memory abilities of students.

The whole application includes (a) two assessment tasks that are assessing the acquisition of new words of the participants, (b) an exercise that has been created to strengthen the verbal working memory of the participants, and (c) the administration panel of the entire application. Both assessment tasks as well as the exercise have been designed according to the principles of game design. The application is based on open and modern technologies (i.e. HTML5 and JavaScript).

The paper is structured as follows: the next section presents related work on cognitive training games supporting number recall and language learning. After that, the design and development of the application are presented. Next the usability evaluation process and results are presented. The last section presents the concluding remarks and our future steps.

## Related work

This section presents cognitive training games supporting digits recall and language learning. The following list presents an overview of existing cognitive training games supporting digits recall.

- CogmedQM (http://www.cogmed.com/qm): Paid games with digit recall tasks for adults in English with good GUI (4/5) and available in PC. Among its functionality there are rewards, score as well as user help and support.

- Cambridge Brain Sciences (http://goo.gl/NXGIF5): Free games with digit recall tasks addressed to all age groups in English with excellent GUI (5/5) and accessible from the PC. The application enables the user three attempts and the possibility of performance observation. Among its functionality there are rewards and score. The main disadvantage is the usage of Flash technology, which is outdated nowadays.
- Lumosity Moneycomb (http://www.lumosity.com): Paid (for full access) game with digit recall tasks in English with excellent graphical interface (5/5) and accessible from the PC and mobile devices. Among its functionality there are rewards, score as well as user help and support.
- Brain Age Test 01 (http://goo.gl/1ja5oE): Free digit recall game in English and Japanese language with poor GUI (1/5) and accessible from the PC. It claims to determine the age of the brain. Among its functionality there are rewards and score. The main disadvantage is the usage of Flash technology, which is outdated nowadays.
- Memory test (https://goo.gl/5Bm3XD): Free game with digit recall tasks in Greek language with unsatisfactory GUI (2/5) accessible from mobile devices. Among its functionality there are rewards and score. The main disadvantage is the limited number of courses.
- Brain games – immediate memory (https://goo.gl/sgRLd5): Free game with serial digit recall task in English with moderate GUI (3/5) accessible from mobile devices. Among its functionality there are rewards, score as well as time limit. The main disadvantage is the inability to retain difficulty level in case of loss.
- Brain Fitness (brain training) (https://goo.gl/26hcUZ): Free game with digit recall in English consisting of 10 rounds with moderate GUI (3/5) accessible from mobile devices. Among its functionality there are rewards, score as well as user help and support. The main disadvantage is that it can display only 5 digits.
- Brain trainer (https://goo.gl/e8cFnA): Free games memorizing series of digits and names and games recall previous digits in English with good graphical interface (4/5) and accessible from mobile devices. Among its functionality there are rewards, score as well as time limit. The main disadvantage is the high difficulty of the game which is not introduced in an increasing way to the user.
- Brain Training (https://goo.gl/Qgn3C5): Free game with digit recalling task in English with moderate GUI (3/5) accessible from mobile devices. Among its functionality there are rewards, score as well as help and support.
- Super Brain (https://goo.gl/Qgn3C5): Free game with digit recall tasks with abstract graphical interface (5/5) and accessible from mobile devices. Among its functionality there are rewards, score, time limit as well as help and support. The main problem is the possibility of malfunction in the touch screen of a mobile device (drag and drop).

The following list presents an overview of technological solutions for language learning. It should be noted that the learning language is English and that all applications are free and are associated with learning new words.

- Memory Flashcard – Fruit (http://goo.gl/KZj0Z7): Full process of display- learning-evaluation with the use of a word in a sentence. Use of Flash (which means limited access from mobile devices) technology and poor GUI (1/5). During learning there is the ability to set time features, while the exercise can be performed in any time. It supports rewards and score.

- English Vocabulary Test (http://goo.gl/SzuNE1): Simple presentation of new words after selection.
- Based on Html & Javascript with poor GUI (1/5). There is no time limit. It supports rewards, score and help. The main problem is that the environment is poor.
- Classroom Words - Picture Matching Quiz (http://goo.gl/C2XFbh): Full process of display- learning-evaluation where there is evaluation of only 6 school items. Use of Flash technology and dissatisfying GUI (2/5). The learning and the exercise and can be performed in any time. It supports basic functionality of rewards and score.
- English Vocabulary game (http://goo.gl/fQAqzT): Process of image and sound presentation which includes evaluation process, uses Flash technology with moderate GUI (3/5). The exercise can be performed in any time. It supports rewards, score and help. There is limited functionality for correction in case of error.
- Food Vocabulary (https://goo.gl/B9ntNg): Evaluation process, based on Html & Javascript moderate GUI (3/5). The exercise can be performed in any time. Displays success and percentage of correct answers.
- Animals (http://goo.gl/eK3lKw): Evaluation process using drag and drop, based on Html & Javascript poor GUI (1/5). The exercise can be performed in any time. There is no support for rewards. It just displays the number of wrong answers. Poor GUI, a small number of words for evaluation and lack of prior presentation of new objects.
- Word List Recall (http://goo.gl/XcnjP7): Application of words display which uses Flash technology with poor GUI (1/5). The exercise can be performed in any time. It supports rewards, score and help. The system is unable to control user responses

According to the related work presented in this section it should be noted that there is no application that improve the direct verbal adult memory. Therefore, our application has been designed to this direction. More specifically our application was created for the training of phonological loop.

## Design and development of software application

This section presents the design and development of the software application. First of all the scenario of the game is presented and the task that should be completed by the users. It should be noted the there are two different categories of users, the user player and the user administrator. Then we are presenting the target group and the educational objectives.

## Scenario of the game

Players - users can access the application through an authentication procedure using their personal login and password. Then there are two phases:
- Phonological loop training (digit recall task)
- Pair associated learning (ability to learn new words)

### Phase 1: Pair associated learning (ability to learn new words)

This phase is conducted during the first session. The players initiate the procedure with the psychometric part where the results are shown before using the rated application. Specifically, the player needs to memorize and to match 10 pairs of non-existent words and non-existing images within 10 attempts. The images are displayed while non-existent words are heard (Figure 1).
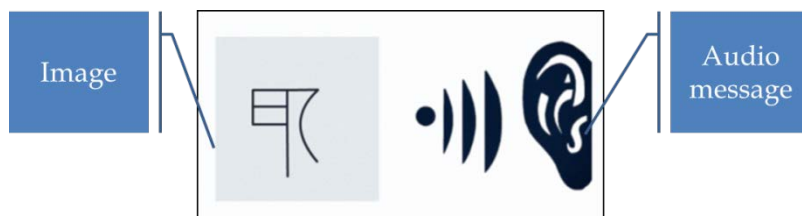
**Figure 1. Display of visualization and production of corresponding audio message**

The 10 pairs of images and the corresponding sound are shown a single time for all the items. During the assessment the user must recognize the representation and type the name in the field of the corresponding non-existing word in capital Greek characters (Figure 2). Also, the user can see the number of correct answers given with the symbol of a star and the number of completed rounds. It is possible to complete the process before the 10 attempts, if two consecutive successful assignments of the 10 pairs are achieved.
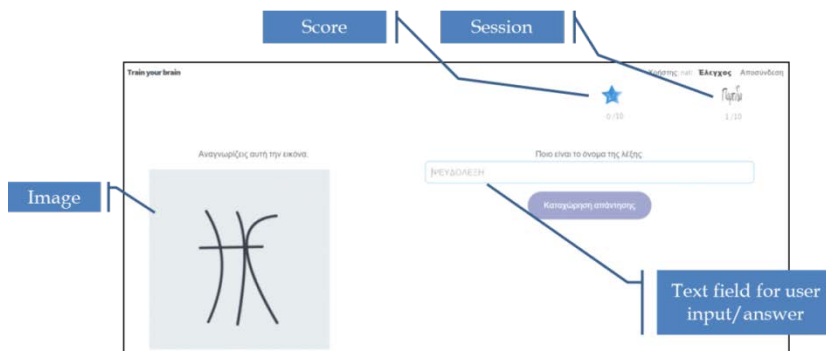


**Figure 1. User interface of user assessment by matching visual and auditory stimuli**

The presentation of images is random. In case of correct or incorrect submitting of the non-existing word, the following screen together with sound message bearing the correct name of non-existing word is displayed to the user. Simultaneously, the user observes the non-existing word has typed and receives feedback for correct or incorrect answers. In addition, the elements of the score and the number of rounds are retained. Finally, the user has the option to continue to the next non existing word pressing the "Επόμενη" button. To avoid confusion the non-existing word requested by the user are automatically filled in capital letters and all that is expected of him is their submission with Greek characters. For audio formats "i" the phoneme "I" for "e" to use the phoneme "E" and then for "o" to use the phoneme "O" so that no spelling issue is expected to be used. After completing the process it is possible to begin the training through a game of recall of series of numbers and there is no possibility to restart the psychometric part.

## Phase 2: Phonological loop training (digit recall task)

This phase is conducted during the next 10 sessions. For the next 10 sessions the user has the possibility to practice only once daily for 15 minutes. In practice the user takes the role of a burglar who tries to escape from locked rooms memorizing each time random series of

numbers and typing them in the exact order, to open the doors. His purpose is to climb the 14 floors of the skyscraper in which he is trapped in. To go up a floor he needs to unlock six serial doors in other words to memorize six different series of numbers every time. The player, depending on the floor - level of difficulty, watches an according amount of numbers starting the process from the third floor. After the observation the graphical user interface (GUI) changes and the user is asked to enter through the screen keyboard the series of numbers which he memorized. For each successful completion the player is rewarded with different scores depending on the number of consecutive incorrect attempts. In case of successful completion, the GUI changes and there is a visual and audio feedback. In order to get to the next room or floor, the user must press the green arrow (Figure 3).
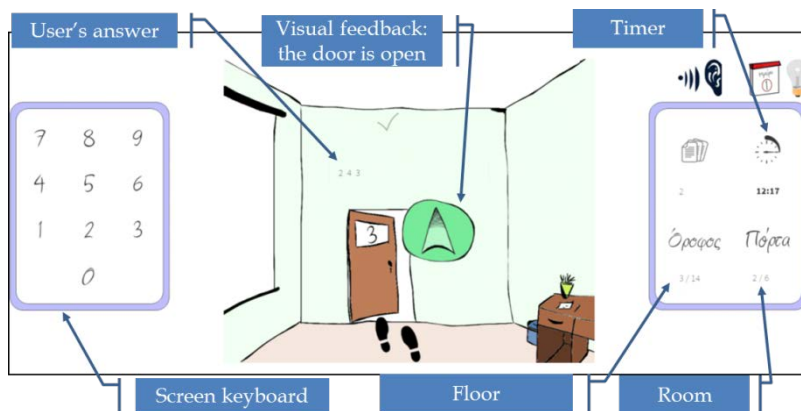


**Figure 3. Successful number submission**

In case of improper registration the GUI changes and there is visual and audio feedback. In order to continue to the next series of numbers the user may select the "Εκκίνηση Αριθμών" button. The difficulty of the game is increased, as each time the player goes up one floor, an extra digit is added in the series of numbers to remember. In case of six repeated failures the requested series of numbers is reduced by one digit and the user descends one floor. After completion of the ten-day practice the application is unlocked and the user is able to initiate the second psychometric part, thus the pair associated learning (ability to learn new words) which is similar to the first and varies in images and non-existing words. Meanwhile, the player has the ability to supervise his personal performance or of the performance go the top players from the main menu.

The user administrator has the ability to configure the application. The administrator can add and remove users by completing the desired name and password and according messages are automatically displayed by the system in the event of successful registration or deleting of a user. Also, there is the option to observe the list of registered users. For the first and the second evaluation part the administrator is capable to seek and observe the personal performance of each user or add and modify content. After each choice different messages are displayed. The administrator can observe the past performance of users during the training period and see the two best players. Finally, it is possible to compare the two evaluation arts for direct observation of the individual performance of the users.

## Target group and goals

The application is addressed to young students over 18 years old. We have decided to implement the user interface of the prototype version of the application in the Greek language to avoid ambiguity or misunderstanding of the content, the program instructions are given written and in video format. The main goal is to improve performance in the time of learning new words, thus to increase the speed of learning. It is expected that after the completion of the application the users to perform in a shorter time and with the least possible effort in relation to their performance before the start of the educational process. In addition, the aim is to reduce the number of attempts made by the user to achieve the desired result. In practice the goal is to increase user performance and maintain user interest.

## Technical issues

Concerning the technological infrastructure, the main concern was to offer easy and quick access from distance. Therefore the application is web-based implemented using modern, secure and open technologies and standards for supporting every web-browser and mobile device. The application has been developed from scratch HTML5, css3, JavaScript, Ajax, and jQuery (version 2.2.0).

## Usability evaluation of the application

A questionnaire was used for sample collection that was distributed to a random sample of students. The survey involved 27 volunteer young adults, who were Greek students. The questionnaire was electronically distributed and included demographic questions, level determination education and questions for the knowledge in foreign languages. Moreover, it included determining questions of computer skills and use of the Internet.

After the process a second digital format questionnaire was used, called the weighted questionnaire "USE Questionnaire: Usefulness, Satisfaction, and Ease of use" based at Lund questionnaire (2001), which includes 30 questions to determine the usefulness, ease use, ease of learning and satisfaction of students by using this particular application. They used the system log files to determine the number of attempts to successfully complete psychometric parts and the data recorded on the daily practice of players.

The results of the second questionnaire were used to collect information about concerning the usefulness, ease of use, ease of learning, and the users' satisfaction of the application. The opinion of the students is positive concerning (a) the usefulness of the application (mean 4.78/7), (b) the ease of use of the application (mean 5.54/7), (c) the ease of learning of the application (mean 6.48/7) and (d) the satisfaction of the use of the application (mean 5.16/7).

## Conclusion

This project filled a gap in the availability of applications that improve the immediate verbal memory among adults. For the application the questionnaire showed positive attitude of the participants about usefulness, its ease of use, its ease of learning and its satisfaction of use. There was neutral to slightly negative opinion from the participants regarding the lack of error correction while typing the series of numbers in the game. Also, it was not possible to determine the value of the application for the possibilities it can offer, as it was not

considered necessary to some of the students. On the other hand, there is still room for improvement of the application and specifically there should be recoverability of incorrect mistypings in the 2nd game, which displeased participants. Moreover, in order to have absolute independence of the administrator by the programmer it is needed to enable adding sounds to the server without the intervention of the programmer. Another future step is the evaluation of the participant's ability to learn new words through the use of a laboratory task with a pair association learning paradigm that simulates the natural process of learning new words. Participants were invited to this project to learn associations of non-existing words and images. The assessment of learning new words was made before and after the completion of the training, which lasted two weeks. Preliminary result showed that participants who completed the training process significantly improved their immediate working memory and their speed of learning new verbal material.

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