

# Training Working Memory in Elderly People with a Computer-Based Tool

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**Abstract.** Working Memory (WM) is a fundamental system to allow the execution of many cognitive functions (learning, reasoning, reading, language comprehension, calculation, etc.) involved in daily activities. WM declines with aging but can be improved with training programs, including computer-based ones. This paper presents a free and open source web platform called VIR-TRAEEL that consists of activities to train several cognitive skills, including WM. One of its activities, Objects Bag, is described as well as tests performed to show its effectiveness.

**Keywords:** Elderly people · Working memory · Computer-based cognitive training · Web platform

## 1 Introduction

Working memory (WM) is a multi-component system for short-term storage and manipulation of a given amount of information needed to successfully perform a wide range of complex cognitive tasks [1]. The WM model consists of four components: (1) the central executive for controlling the attentional process; (2) the phonological loop; (3) the visuospatial sketchpad for holding verbal and visual information; (4) and the episodic buffer for integrating information across space and time [1]. The WM is a fundamental system that allows the proper execution of many cognitive functions (learning, reasoning, reading, language comprehension, calculation, etc.) involved in daily activities [2]. Moreover, the WM is the component for updating and monitoring the executive function [3] and, consequently, it plays a central role in all goal-oriented behaviours.

However, WM declines in both normal [4] and pathological aging [5]. Although the exact causes of this decline are unknown, findings suggest impairments in the four components of the WM: deficit of efficiency [6] and speed of the central executive [7], and less capacity of the visuospatial sketchpad [8] and the phonological loop [7]. Therefore, to maximize the effectiveness of WM interventions, they should include activities aimed to improve its four components.

In this paper we present VIRTRAE, a computer-based web tool that includes activities to train the WM. In particular, we will describe one of its key WM activities, namely Objects Bag, and the tests performed using it.

## 2 State of Art

Many computer-supported tools for training cognitive skills have been developed in the last few years. Cogmed (<http://cogmed.com>), Cognifit (<http://cognifit.com>), RehaCom (<http://www.rehacom.co.uk>) are the more frequently used computer-based WM training programs. Results with patients with acquired brain injury suggest that Cogmed can not only enhance WM but also cognition and psychological health [8]. However, the effectiveness of WM training is a controversial issue nowadays [9], especially when related to computer-supported training [10]. Melby-Lervag and Hulme [11] analysed the former three tools (and others) and suggest that none of those applications are supported by a detailed task analysis that might be expected to show improvements in the WM capacity. A large randomized controlled trial of this evidence in the elderly is being carried out, so data is currently unavailable [12].

In consequence, while there are some experiences with computer-supported trainings, their underlying theoretical models have not been proven to be suitable for improving WM.

In other work, Cameraio et al. [13] have analysed some training programs designed as serious games for stimulating mental abilities, and Rizo [14] has studied the advantages of virtual reality for the same objective. In both reviews, it can be observed that serious games and virtual reality may improve user involvement and experience during mental stimulation activities. Sík Lányi et al. [15] reviewed the usability and accessibility of 10 serious games that used virtual reality for improving cognitive skills that will help them in their working day. After their analysis they proposed design guidelines for serious games for use by people with intellectual and additional sensory impairments.

## 3 Method

The next subsection introduces VIRTRAE as the underlying platform supporting the Objects Bag activity. Later, the Objects Bag activity itself is described, and the tests that were performed with it are summarized.

### 3.1 VIRTRAE: A Web-Based Platform for Cognitive Stimulation in the Elderly

VIRTRAE (formerly called PESCO [16]), <http://virtrael.es>, is an open source and free web platform developed at the University of Granada, Spain by a multidisciplinary group composed of psychologists, software engineers and doctors.

The platform integrates a computer-based cognitive training program and a set of supporting tools to allow communication between carers (therapists and informal carers) and users (older people), administration of their profiles and access privileges, planning of working sessions with activities for assessment and training, supervision, and evaluation of the users' performance.

VIRTRAEEL provides 18 types of activities to evaluate and train the main cognitive skills: memory, attention, planning and reasoning. We have tested the concurrent validity of these activities and performed a previous pilot study to analyse the users' responses. Some of these activities include 3D virtual-reality environments [17].

Regarding its implementation, the platform is composed of integrated components, each of them related to different tools and functionality.

Standards technologies were used, because the key focus was on its portability, availability and extensibility, in order to allow anytime, anywhere use of the platform and easy integration of future enhancements. To achieve these goals, the contents of the activities are described using XML files. The code with the logic of the activities is written using JavaScript, and they are visualised using HTML and CSS (viewable in any web browser). A database is used to manage user profiles and to store measurements.

Usability and accessibility were other key points in the platform design. VIRTRAEEL was developed taking into account several usability guides for elderly people and accessibility W3C recommendations [16], although the platform cannot be fully accessible because some activities require specific skills to be carried out using visual memory. Training Working Memory using the Objects Bag Activity.

This paper is focused on one of the activities of VIRTRAEEL: Objects Bag. This activity was developed specifically to train WM. Its design, implementation and the measurements that the system takes to analyse user performance will be also described.

Objects Bag presents an avatar (a guide character) with a shopping bag while moving all around a city. Each time the avatar moves to a new place or shop depicted in a city map (Fig. 1), it can pick up or drop objects.



**Fig. 1.** A map with eight different places and instructions.

The quantities and specific objects to be picked up or dropped vary along the ride. Users are asked to pay attention and keep in their memory all operations performed by the avatar (Fig. 2).

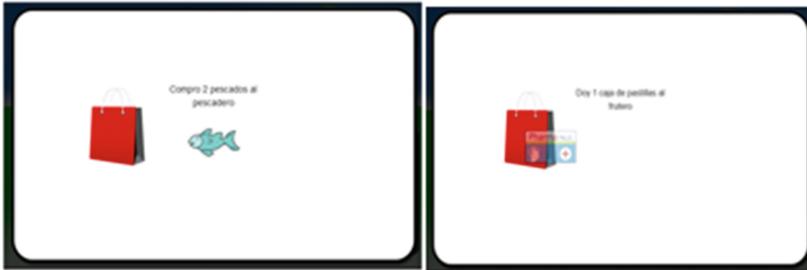


Fig. 2. Representation of how objects are introduced (left) into the bag or dropped (right).

To fully understand the task, written instructions are provided, and before starting the activity, a demonstration is done. Additionally, users must also practise through examples. Practices are repeated up to three times if their answers are incorrect. The activity begins when the user has performed the practice satisfactorily.

At the end, users are asked which items, and how many units of each one, are in the bag. The answer is provided through a selection panel (Fig. 3). The activity must be performed four times, varying the places and objects in each one.



Fig. 3. Final panel to choose the type and number of objects inside the bag.

Multiple characteristics make the Objects Bag activity suitable for improving WM:

- It is a complex *goal-oriented task* and therefore it requires the activation of all the four components of the WM. The *central executive* must allocate and control enough attention to input and manage the appropriate information. The *visuospatial sketch-pad* must hold and update visual objects. The *phonological loop* is activated by both instructions and verbal components of the objects, and the user self-statements or rehearsal. *Episodic buffer* must integrate every scene as a whole using information from long-term memory (for calculating and comprehension of the situation).
- It is a systematic training: four trials each time, twice a week for three months.
- It is a dynamic task that has been designed to avoid getting used to it, since each trial presents a different map, varying the shops, places and the objects to be picked up or dropped.
- In each trial the difficulty is graded, and it increases if more correct answers are provided.

VIRTRAEEL performs several measurements while the users are performing this activity (and many others integrated into the overall platform), also allowing the therapists to supervise them. The measures that are taken are: time to read the instructions, total time to perform each trial, and the raw number of successes, failures and omissions (for each trial). To maintain and increase motivation for training, feedback is provided on the raw score achieved in each session. A visual feedback is also provided in the form of a bronze, silver or gold medal, depending on the performance level (Fig. 4). It is as a prize to the user.



**Fig. 4.** Feedback shown when the activity finishes. (English translation: “Congratulations. ¡It is not bad at all!. You have won a bronze medal. Let’s continue training to get a silver or gold medal. You can repeat the activity by pushing the button).

To improve the applicability of the training to real environments, the Objects Bag activity presents an avatar resembling common activities that are done every day while shopping and walking around a city.

### 3.2 Tests

The effectiveness and usability of the Objects Bag was tested in a previous study with older people. Findings indicated that the experimental group of 36 users of VIRTRAEEL showed a significant improvement in WM against a control group of 34 users who spent the same time doing recreational computer use [15]. Although this was not a randomized controlled trial, controls in the study design and specification of tasks and variables allow us to draw conclusions about the benefits of applying a scientific model to the training activities.

Some tests are currently being carried out again, since new activities have been added to the platform, including 3D activities and a recommendation system about nutrition. The usability of the activities has also been improved.

## 4 Conclusions and Planned Activities

Objects Bag is a specific activity and tool for computerized training of WM. It is integrated into VIRTRAEEL, a free and open-source web platform. The activity has been designed following a theoretical evidence-based model of WM. It has demonstrated its usability for the elderly and its motivational qualities. Activities used in the Objects Bag tool are everyday activities, so future studies will determine whether the improvements made in WM are, in fact, transferred to real life, one of the main challenges of computer-based training.

Finally, the features of VIRTRAEEL can provide a real social impact: it is a free and online tool that allows widespread use for training elderly people. Moreover, its use can be independent or supported by relatives or therapists, from homes, community classrooms, day centers, residences, etc. In fact, as its benefits are being demonstrated, some public institutions (such as the social services of municipalities of several villages and a regional consortium of business and local governments called Consorcio Fernando de los Rios) are interested in VIRTRAEEL to train their elderly citizens. They are collaborating by providing resources and space for the tests.

The social and health impact of any action to minimize cognitive impairment would be enormous due to an aging population and the high rates of dementia. Objects Bag has also demonstrated the benefits of applying evidence-based models of neuroscience in tool design.

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