# Design guide and usability questionnaire to develop and assess VIRTRAEL, a web-based cognitive training tool for the elderly

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# Design guide and usability questionnaire to develop and assess VIRTRAEL, a web-based cognitive training tool for the elderly

In most developed countries, the population is gradually ageing. Due to this, there is an increasing demand for technologies whose design is specifically oriented towards meeting the needs of the elderly. In this paper, we describe a web-based cognitive training tool for elderly people, called VIRTRAEL, which comprises 18 exercises presented in 13 working sessions. In order to reach a high degree of user acceptance, we have applied a user-centred development methodology and a guide defining a set of design principles and usability guidelines specifically intended for older people. Moreover, a usability questionnaire to assess VIRTRAEL has been especially designed to be completed by this type of users. Both guide and questionnaire can be easily applied in other software developments, and especially in those related to the specific domain of cognitive training for this user group. As a means to objectively measure the usability of VIRTRAEL, an EFA (Exploratory Factor Analysis) has been conducted on a 32-item questionnaire with 149 subjects. The results confirm that our proposal is usable and highlight some differences between user groups (female versus male users, and those who live alone versus those living with other people) that should be taken into consideration in future developments.

Keywords: usability; design guide; web-based tool; cognitive training; elderly people

## 1. Introduction

As is well known, the population is ageing in developed countries (UN-DESA-PD 2017). In fact, the 65+-year-old adults will be about 40% of the total population in the European Union by 2060 (EC 2014), while this population group will be about 52% in the United States (Colby and Ortman 2015).

Older people are a very heterogeneous group made up of people with not only different functional and motivational capabilities, but also with a varied experience of technology (Newell et al. 2006). In fact, older adults have a wide range of educational levels, with a significant proportion having low literacy, and the amount of free time and flexibility that they have vary from people with extremely busy lives to others living alone, isolated and with a large amount of free time (Dickinson, Arnott, and Prior 2007). Besides, most older adults are not comfortable with technology because of usability issues, and they do not understand the benefits of technology, have not been trained to use it or have used it very little (Hart, Chaparro, and Halcomb 2008). Moreover, most people over 65 years of age have never used the Internet. However, the number of older adults that use the Web is increasing; in fact, more than half of older adults in the USA use the Internet and smartphones (Smith 2014). In addition to all these aspects, we should mention that the main changes related to ageing are (Arch 2008; Costa-Ferrer et al. 2013; Nunes, Silva, and Abrantes 2010):

- Physical, such as: Decrease of both strength and manual dexterity; Alteration in coordination mechanisms and control; Diseases such as Arthritis or Parkinson’s; Changes in size, proportions and articular ranges, for example, in the mobility (flexion and extension) of wrists, fingers and legs (ankles and knees).
- Sensorial, affecting:
    - Vision: Decrease in visual acuity; Reduction of visual field; Presbyopia; Increase in sensitivity to blinding; Decrease in the capability to focus objects (including a computer screen), to adapt to the dark and to perceive colours; Sensitivity to contrasts and binocular perception also decrease; Pupil shrinkage (need for more light); Diseases of

the eyes, such as cataracts; and Age-related macular degeneration.

  - Hearing: Difficulties in locating sounds and recognizing voices; Loss of sensation of pure tones; Binaural listening; Increase in the sensitivity to loudness; Difficulties in perceiving high frequencies.
  - Touch: Decrease in tactile sensitivity to discriminate forms and textures.

- Cognitive: Loss of neurons affecting different capabilities such as memory and attention. This depends on genetics, ambient factors and person behaviour. The cognitive decline is associated with a loss of functional tasks (Njegovan et al. 2001), which affects to the normal development of (basic, instrumental, leisure and work) activities of daily living (ADLs). The most affected ADLs are the instrumental ones, such as shopping, cooking, and banking (Jekel et al. 2015). Therefore, as the neuronal plasticity continues during all of life, it is important to maintain an active brain by means of a cognitive training (Owen et al. 2010) because this is beneficial for improving the performance of ADLs and the quality of life, as well as the well-being of older adults. Working-memory and episodic memory are particularly impaired. This affects the older adults' perception and comprehension of their environment. Dementia and Alzheimer's disease are the main cause. Working memory declines by normal ageing, influencing the learning process and language comprehension. Semantic, prospective and procedural memory declines minimally. The learning of new processes or event-based reminders are the most affected ones and should be enhanced (Nunes, Silva, and Abrantes 2010). Moreover, Connor (2001) reviewed the literature to discover which memory skills decline and which are preserved due to ageing. She concluded that memory tasks requiring a high degree of effort, such as free recall and working memory activities are the most affected, as well as context memory which was much poorer than remembering contents in older adults. Finally, she showed that memory training is more successful when the memory training process is enhanced, rather than when only encoding is trained.

The MacArthur Aging Model (Rowe and Kahn 1997) indicates that there are three main components influencing the successful aging:

*avoiding disease and disease-related disability*, the *maintenance of high mental and physical function*, and the *continued engagement with life*. Consequently, it is very important to maintain cognitive abilities in old age for proper functioning at home and in the community. For example, learning activities for older adults promote an active aging and an engaged lifestyle that help them to maintain their cognitive abilities, increase their social interactions and contribute to the wellness of their environments, families and communities (Boulton-Lewis, 2010). Technology can be used for educational purposes with this population, though each of the previously mentioned changes affecting to this group has important implications for its use, especially when the elderly people have impairments (Wagner, Hassanein, and Head 2010). Sayago and Blat (2009) highlight the problems of elderly people when interacting with computers due mainly to a lack of experience and decline in functional abilities: difficulties in remembering steps, understanding the web and computer jargon, and difficulties using the mouse. These difficulties are more important than those caused by physical impairments due to ageing. The authors conclude that they are barriers to independency (the ability to use ICT –Information and Communications Technology– on their own) and inclusiveness (due to special assistance not being needed).

Designers cannot ignore this growing population and have to design with them in mind (Zaphiris, Ghiawadwala, and Mughal 2005). W3C is leading the development of educational resources for developers serving ageing communities, providing guidelines and techniques to apply to the software applications aimed at them: WAI-AGE (Web Accessibility Initiative: Ageing Education and Harmonisation) project (Brewer et al. 2012). Arch (2009a) describes some of the challenges of enhancing web accessibility for all users and suggests that developers have to learn design guidelines, as well as better understand and accommodate their designs to older people’s needs. As the accessibility perceived by the users is related to the user experience, its evaluation by the users can be different from the conformance to usability guidelines (Aizpurua, Harper, and Vigo, 2016). Therefore, the user's opinion has to be considered because it is more pragmatic and complements the heuristic evaluations on the usability and accessibility of an application performed by experts.

Our research group has extensive experience in the development of learning and training systems for diverse groups with special needs. Precisely because of this, these systems have been designed with a high degree of usability. A couple of illustrative examples of this type of systems developed by our team are: PICAA (Fernández-López et al. 2013), which is a mobile learning platform to train basic skills (language, maths, environmental awareness, autonomy and social skills) that allows the creation of customized and adaptable applications, tailored to each user's needs and learning objectives, specially intended for children with special educational needs; and SIGUEME (Vélez-Coto et al. 2017), which is a multiplatform application to train attention and the perceptual and visual cognitive skills required to work with and understand graphic materials and objects, designed for children with low-functioning ASD (Autism Spectrum Disorder) and other disabilities.

Taking all this into account, the present article presents a web-based cognitive training tool, called VIRTRAEL. This tool is in line with the Rowe and Kahn (1997)'s aging model above mentioned because it helps to maintain and even improve the cognitive function in late life. In their revisited Successful Aging 2.0 model (Rowe and Kahn 2015), they include, among others, the adoption of a life course perspective, which implies that changes introduce in one stage of the life may influence the needs and opportunities at next stages. In this sense, we think that our tool could also be used in early stages of the life and not only at the late life.

VIRTRAEL has been specifically designed for the elderly and developed by applying a guide with both design principles and usability guidelines that we have created based on other previous similar guides. Moreover, we include the results and an analysis of an assessment of our tool carried out by the users. To carry out this assessment, we have used a usability questionnaire especially design to be completed by older users. We think that both instruments that we propose (guide and questionnaire) can be respectively applied to the development of other software applications targeted to the same population and to their assessment. Moreover, we present the results obtained from the assessment carried out in a study with a high participation (149 subjects).

The remainder of the article is organized as follows: Section 2 presents related work. Section 3 describes VIRTRAEL and the usability principles applied to it. Section 4 is focused on the methodology followed in the pilot study we have carried out to assess our tool. Section 5 shows the results obtained and analyses them. Finally, Section 6 outlines conclusions and future work.

## 2. Related work

This section is divided into two subsections: The former presents some work related to usability assessment via tests by elderly people. Software designers have to take into account their characteristics and responses to these tests, as a complement to the heuristic evaluations carried out by experts, to improve the usability and accessibility of the applications intended for this type of user. In the second subsection, as the tool we present in this article belongs to the specific domain of cognitive assessment and training for older people, we also analyse some related tools existing in this domain.

### ***2.1. Usability assessment by elderly people***

In this section, we firstly present some work related to the usability assessment of technology (in general) by elderly people. Secondly, the ones related to the usability assessment of web applications. Thirdly, the work related to the usability assessment of mobile applications. And finally, the conclusions of the review study carried out in this section.

#### *2.2.1. Usability assessment of technology*

A recent study (Guner and Acarturk 2018) evaluates the acceptance of ICT by older people. In it, the Technology Acceptance Model (TAM) is used to show differences between elderly and young adults. The two items more related to usability, perceived usefulness and perceived ease of use, were best valuated by older people than by younger people, with a significant impact in attitude and acceptance. However, the behavioural intention to use ICT was lower for the older people, perhaps due to generational characteristic, according to the authors.

In other study, Díaz-Prieto and García-Sánchez (2016) present a large questionnaire about barriers that elderly people perceive when they use technology. These barriers are classified in three groups: intrapersonal (related to feelings), contextual (learning and social environment, cost of technology) and tools (privacy, accessibility and usability). The authors show that there are differences in the test answers according to the type of tool, age and educational level of the responder.

There are other studies which concluded that elderly people can accept ICTs as a help to improve their quality of life. One of them is the one carried out by Merriman et al. (2018) who taken into account the acceptance of technology by older adults in the performing of activities to specifically evaluate the acceptability of a personalized game in order to improve balance confidence and spatial cognition using questionnaires. Other study in a similar line is the one proposed by Costa, Veloso, et al. (2018), in which a set of psychosocial variables and design domains were identified so that serious game developers can encourage older adults' active ageing, well-being and quality of life.

With the aim of improving the social support network and quality of life of the elderly population through the use of new technologies, Castilla et al. (2018) carried out a case study in a rural area, showing the usefulness of a social network with linear navigation in the context of digital literacy for elderly users. They used the system Butler 2.0, an open leisure-oriented social network with a sample of 46 participants between 60-76 years old with heterogeneous previous experience in ICT. For the study, the authors defined instruments for collect different data: user profile, opinion about ICTs, usability and acceptability items, satisfaction on ICT use, and preferred learning method.  In addition, the authors also obtained qualitative information through focus group with end users. Study results indicated that there were differences in perceived usefulness between users with high and low ICT experience.

Another study in which elderly people participated, performing a usability test in relation with technology in general, was carried out by Akatsu and Miki (2004). Their objective was studying the effects of cognitive ageing and behavioural characteristics of the elderly using technology. This study revealed that older people require twice as much time as younger users for withdrawals and three times as much time for found transfers. Besides, other differences are: the elderly respond better to items that are easily seen or can be touched directly by hand, they do not readily notice changes in information displayed in the screen, they have problems in extracting the necessary information of a text, and they do not usually act/interact independently, but just follow orders without thinking why. Despite the elderly's cognitive capacity deterioration, these authors think that there are other relevant factors that influence the interaction of the elderly with ICTs. The first one is their attitude, related to cultural and social values. The second one is the lack of knowledge and mental models about how to use specific technologies. Wagner, Hassanein, and Head (2014) also agree with this, demonstrating that if the users do not have a clear mental model, their level of disorientation will increase, and their performance and satisfaction will decrease. A third factor, mentioned by Castilla et al. (2016), is the navigation relevance in systems with linear navigation oriented toward the elderly, because it reduces the involvement of executive functions when the users are performing the exercises.

*2.2.2. Usability assessment of websites*

Related to the use of websites by the elderly, Redish and Chisnell (2004) prepared a review of research in website design for older adults. They analysed in detail the main aspects influencing the elderly response when using websites: their age, their previous use of computers, vision difficulties, reading level, difficulties in understanding the objectives, structure, organization and presentation of the information, their positive or negative attitude (including confidence level and emotional state before and after the use) and place of use (own house, family house, classroom,…). These authors highlighted the importance of user-centred design and presented good practices to conduct usability studies with older adults.

In another research, Riviera-Navar and Pomales-García (2010) performed a comparative experimental study between older and less experienced users and younger and more experienced users, testing their satisfaction, disorientation, information recall and task workload (by means of specific questionnaires) about the use of a web-based user interface for e-training. Only satisfaction was higher for elderly users, who were also more disorientated, work loaded and had more difficulties to remember information.

In order to measure the usability of websites by older people, Nahm, Resnick, and Mills (2006) presented a usability questionnaire specifically designed to be completed by older adults, called Perceived Health Web Site Usability Questionnaire (PHWSUQ). This questionnaire has been validated in a study by both usability and gerontology experts. It consist of 15 items distributed among four subscales: satisfaction, ease of use, usefulness and logic, all of them measured on a 7-point Likert scale ranging from very unsatisfied to very satisfied. This study indicated that the items must be written clearly using concrete terms. Its authors took into account that the web had not been part of elderly people’s daily lives, so they concluded that the usability aspects to be implemented must be different for seniors and for teens, for example. According to them, the major limitation of this study was its small sample size (10 older adults) and the need for further psychometric testing with larger samples.

In a similar line, the study of Caboral-Stevens (2015) described a conceptual model, called Use of Technology for Adaptation by Oder Adults and/or those with Low or Limited Literacy (U.S.A.B.I.L.I.T.Y.), explaining and measuring the effect of health-related website design on older adults in terms of their ability and desire to use such websites. The author proposed a questionnaire of 25-items in a Likert scale with score ranging from 1 (strong disagree) to 5 (strong agree), based on the already mentioned PHWSUQ (Nahm, Resnick, and Mills 2006) and the Post-Study System Usability Questionnaire (PSSUQ) (Fruhling and Lee 2005). The resultant questionnaire identified four usability determinants: efficiency, learnability, user experience and perceived control. This research also presented a pilot study with 50 older adults.

A more complete proposal was presented by Patsoule and Koutsabasis (2014), with 47 guidelines for web design for older adults, which were based on a representative literature review. In this case, the objective was the redesign of a touristic web portal using the mentioned guidelines. After the redesign, 3 experts performed a heuristic evaluation, and 12 older users completed a questionnaire and participated in interviews about the usability and accessibility of the updated portal, which was again improved with the suggestions of the experts and older users. The authors highlight the importance of the participation of older adults and the user-centred design methods. They show the usability questionnaire provided to participants, which has 14 questions. We think that some of them are very generic and difficult to understand, because of the vocabulary used, e.g. “There was functionally and visually consistency throughout the website?”.

In a more specific study, Nahm et al. (2004) analysed the usability of health websites by older adults. Their conclusions were that the elderly are very interested in their health and in visiting pages related to this, but their usability has to be improved by applying usability principles related to the needs of older adults in their design. They also suggested that specific techniques for usability testing for older adults should be examined.

With a similar idea, Zaphiris, Pfeil, and Xhixho (2009) observed that older people are accessing the Internet increasingly, being one of their main interests the search for healthcare information. These authors propose 38 inclusive design guidelines, called SilverWeb, which are sorted into 11 categories and used to perform a heuristic evaluation by 16 older web users. Each guideline was presented individually with an example of application, and evaluated by the elderly user and an expert who engaged in dialog about it. This dialog allowed problems in the guidelines or in the evaluation process to be detected. The study collected also the preferences of the users about web contents and web interactions. However, it did not propose any usability questionnaire for the elderly but only the heuristic evaluation.

#### *2.2.3. Usability assessment of mobile applications*

Related to the specific use of apps by elderly people, it is worth to mention the recent work of Wildenbos et al. (2019), which assess the usability problems of older patients using two mHealth apps. They use a framework, called MOLD-US, to identify (motivational, cognitive, physical and perception) ageing barriers in a case-study approach, executing the Think Aloud method. Although they conclude that the framework is a valid tool, they propose the use of assessment methods more suitable to older patient’s characteristics, because the Think Aloud method requires certain attention by the participants and this decreases their performance in the own tasks carried out.

Due to the explosion of the mobile applications in recent years and the need that these apps are accessible by older people, this type of studies which put the focus on their usability, especially intended for elderly people, is very important and an example to follow by others researchers and developers.

### *2.2.4. Conclusions of this review study*

After this review, we can conclude that the participation of elderly people in the development process, and specifically in the usability assessment, helps to improve the design of the tools and their acceptance. Some studies use usability questionnaires to measure it; however, the items included in them so far are very generic usability concepts and do not take into account the limitations (motivational, cognitive, physical and perceptual barriers) that older people have when interacting with software systems.

### *2.2. Tools for cognitive assessment and training*

The following studies are related to cognitive assessment and intervention. They will be described in more detail because of their closer relationship to our tool.

González-Abraldes et al. (2010) analysed the usability and accessibility of two of the main computer-assisted applications for cognitive training used in Spain: Gradior and Smartbrain. In their study, 8 elderly people completed a usability and accessibility questionnaire with 22 items. The results of their analysis were that elderly people had difficulties in using the mouse as well as understanding the functionality of icons and the explanations of the exercises. Besides, the exercises were not adaptable to the users' cognitive level. The authors also presented a new tool, called Telecognitio, which is more usable and accessible, and which also provides auto-adaptability according to the user's cognitive decline.

Doherty, Coyle, and Matthews (2010) provided recommendations and guidelines for the design and evaluation of mental health technologies by following a user-centred and participatory design, but taking into account that Human–Computer Interaction and

Health professionals have to be part of the design team. This allows the number of people with access to professional support to be increased as well as improving the effectiveness of the treatments and the engagement level of the users with their treatments.
According to these authors, the main requirements of mental healthcare settings are: Adhering to international and local ethical requirements; building on accepted theoretical models of mental healthcare; making clear the data privacy and security; providing an adaptable, sustainable and tangible system; and evaluating it in clinical practice and in several distinct stages.
Owen et al. (2010) reported the results of a six-week study with almost 11500 participants trained online on cognitive tasks to improve reasoning, memory, planning, visuospatial skills and attention. The users improved their responses but were not able to transfer effects to related untrained tasks.
Åkerlund et al. (2013) used the computer-based tool Cogmed QM to train people with brain injury, concluding that patients improved their working memory and reported less depressive symptoms.

Dobosz et al. (2014) analysed how exercises of rehabilitation of memory for elderly people can be adapted to mobile devices to decrease the complexity of interaction. They suggested that allowing the repetition of the performing of exercises is beneficious. Besides, they proposed classifying the exercises in categories, providing multimedia resources, introducing different difficulty levels, and measuring and controlling the user's workout results.

As can be seen, there are few studies that present results of having performed a usability test for a given application with the participation of a large group of older users. In the case of cognitive training tools for the elderly, it is clear that this kind of tool improves the cognitive skills of the users, but their usability must also be evaluated.

We can conclude that none of the papers analysed present a complete process of usability assessment, which includes the previous design of a tool to be usable by older people, the description of the tool, the selection of usability and accessibility guidelines to evaluate it, the participation of older people in the assessment, the analysis of the data obtained, and finally the improvement of the tool based on the results of that analysis. Most of the examined papers analyses existing tools and applications, but only three of them present usability questionnaires or surveys that have been specifically designed for older people, though they only include very generic questions which are not directly related to the limitations of the elderly.

Taking into account the results and conclusions obtained in the papers mentioned in this section, we have applied many of the recommendations given in these papers to both the development of the tool we present here and its assessment by its users (i.e., older people). In the next sections, we present the main features of our tool and the usability principles applied in it, as well as the testing carried out to assess its usability by the elderly users, providing finally the results and conclusions obtained.

## 3. Overview of VIRTRAEL

In this section, we describe VIRTRAEL. We also present the usability principles applied during its design and implementation.

### *3.1. Description of VIRTRAEL*

VIRTRAEL (Rodríguez-Fórtiz et al. 2015), which is the acronym for *VIRtual TRAining for the ELderly*, is the name of a web-based tool that we have developed to cognitively assess, stimulate and train the elderly. In a certain sense, it can be considered as the evolution of a previous tool for Linux systems, called PESCO (López-Martínez et al. 2011; Rute-Pérez et al. 2014), since VIRTRAEL includes a web-based version of many of PESCO's exercises as well as others explicitly designed for the new tool. Among these latter, several 3D serious games (Rodríguez-Fórtiz et al. 2016) have been implemented using virtual reality techniques. In this way, a series of realistic virtual scenarios related to activities of daily living, such as the ones shown in Fig. 1, have been created in order to facilitate the transfer of the gaming experience to similar real life situations. Consequently, VIRTRAEL can be considered as a personalized assistant (Hornos et al. 2018) or even as a cognitive assistant (Costa, Novais, et al. 2018).


**Fig. 1.** Two examples of 3D scenarios designed for an exercise included in VIRTRAEL. They serve to train memory, attention, planning and reasoning by simulating ADLs, such as going to the supermarket, where the user has to buy the products listed in a shopping list.

Two of the main objectives of VIRTRAEL are: (1) the improvement or at least the maintenance of certain cognitive skills by older people, carrying out the exercises included in the tool from anywhere with an Internet connection; and (2) allowing the therapists not only to configure the activities to be carried out by their patients within the tool, but also to supervise them, and as a result to adapt the corresponding exercises in real time (Rodríguez-Domínguez et al. 2016).

VIRTRAEL contains a total of 18 different exercises. With them, we have predefined 13 working sessions; in each of them several exercises must be performed. The first two and the last two sessions are dedicated to evaluating certain cognitive skills of the user before and after the stimulation or training of such abilities (that is why they are respectively called pre- and post-screening), which is carried out in the rest of the sessions.

Each of these exercises (implemented as 2D or 3D serious games) has been intended to either assess or train (depending on the session where it is run) one or several of these cognitive functions: attention, memory, planning and reasoning. A detailed explanation and analysis of some of these exercises can be found in the papers written by López-Martínez et al. (2011), Rodríguez-Fórtiz et al. (2016), Rute-Pérez et al. (2016), and Hornos et al. (2018).

As an example, Fig. 2 shows a screenshot of one of the exercises included in our tool. This exercise, which is intended to mainly stimulate visuospatial attention and also to train categorical reasoning, consists in putting messy objects in the right place and room as well as collecting the coins lying on the floor. Initially, the exercise displays the corridor that gives access to the different rooms of the house, where a series of objects are placed in them. Once the user has entered a room, the objects that can be moved are shown surrounded by a rectangle with a dashed line.

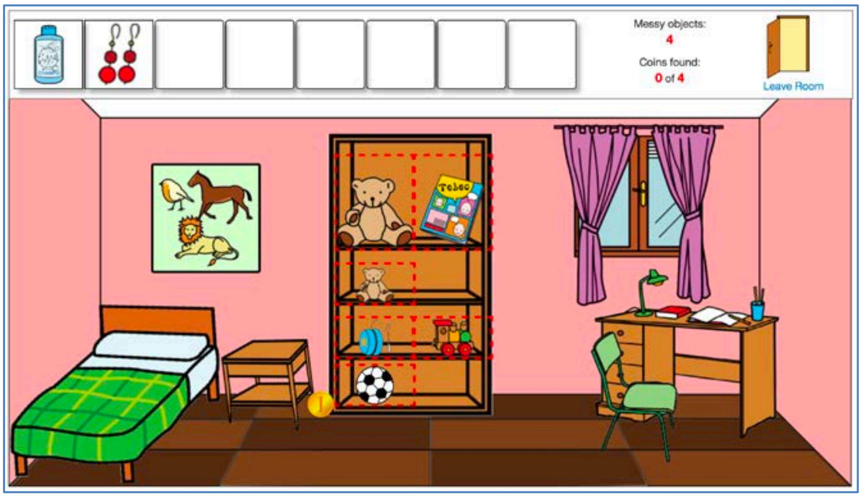


**Fig. 2.** Exercise to train visuospatial attention and categorical reasoning.

Other examples of exercises included in VIRTRAEL are: the one presented in Fig. 3, which is designed to assess and train attention; the one in Fig. 4, which is especially intended for stimulating the working memory; the one in Fig. 5, which corresponds to an exercise to evaluate and stimulate reasoning; and the one in Fig. 6, which is devoted to planning.

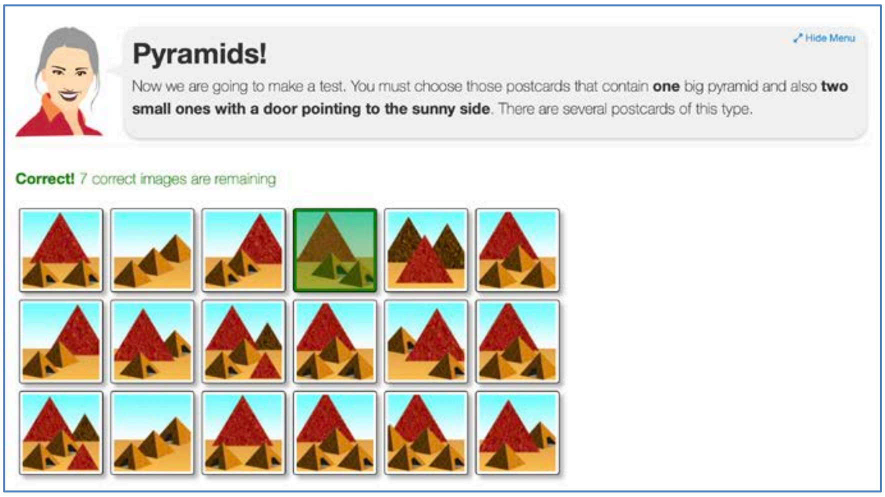


**Fig. 3.** Exercise for choosing postcards with pyramids, conceived to assess and train attention.

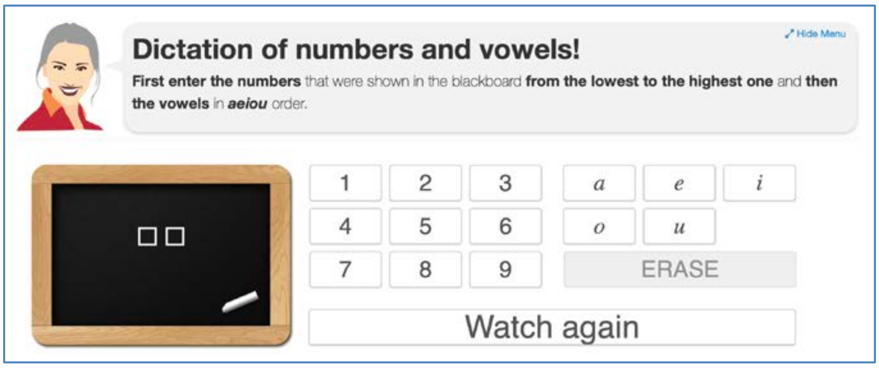


**Fig. 4.** Exercise on dictation of numbers and vowels, designed to train the working memory.

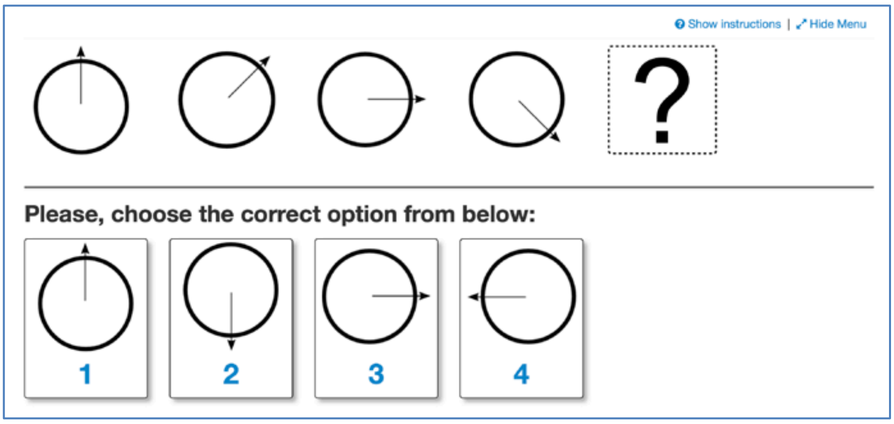


**Fig. 5.** Exercise on logical series, created to asses and stimulate reasoning.

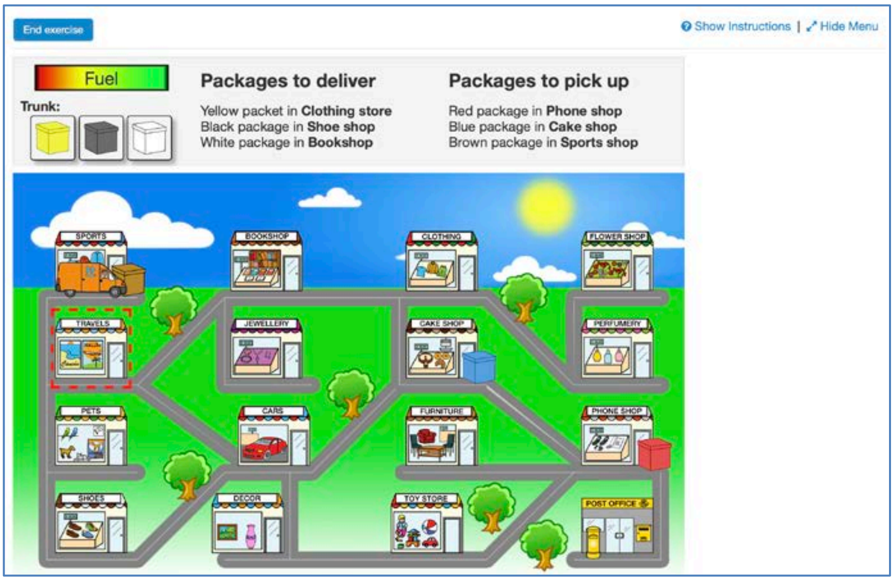


**Fig. 6.** Exercise to deliver and pick up a series of packages to/from different shops, designed to train the users in planning.

As the elderly are the target audience of our tool, in order to guide the user and facilitate the understanding of what she/he must do in each exercise, a character presents the suitable instructions to her/him when each exercise starts (e.g., see top of the screenshots shown in Fig. 3 and Fig. 4). This information is shown via a textual interface instead of sounds because the inclusion of the latter presented both lack of support and compatibility problems in some of the web browsers more commonly used currently. This character is also in charge of telling the user to repeat an exercise or trial (a few times more) when her/his results have not been good. Besides, it has to give feedback to the user after performing the corresponding exercise, either congratulating her/him, in the case of good results, or encouraging her/him to perform it better next time, when bad results are got by the user (an example of this is shown in Fig. 7).

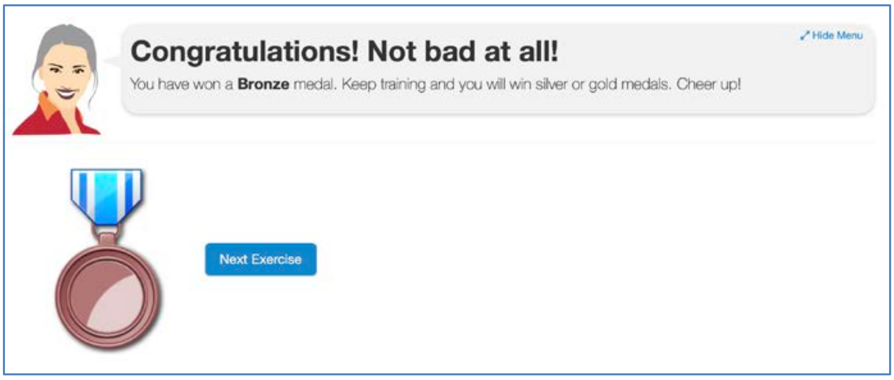


**Fig. 7.** Feedback given to the user after completing an exercise; in this case, encouraging her/him to do it better next time.

Once the mentioned character presents the instructions about what the user have to do in the corresponding exercise, she/he should perform a series of actions to complete the exercise. Among them, we can mention: pressing a key when a certain sequence of events happens, writing a given chain of letters and/or numbers, and choosing one or more items from the set of (graphical or textual) elements displayed, to give only a few examples of actions that must be performed in the different exercises.

VIRTRAEL is able to automatically adapt not only the user interface of an exercise but also its difficulty level while the user is carrying it out. To do that, a responsive design has been implemented and the values of certain relevant variables (e.g. device used, number of failures, hits and omissions, execution time, etc.) are registered when the user performs the exercise. Both types of adaptations are carried out via a rule-based system. The action/s corresponding to each rule is/are performed when its predicate is fulfilled. The predicate can be established on the results of an exercise partially performed, the number of trials carried out, the kind of exercise executed, the type of device used, etc., as well as on the cognitive skills and any other personal information saved in the user profile. Examples of actions to be performed when a rule is triggered could be: changing the value of certain variables of the exercise (e.g. the quantity of on-screen elements, the number of possible answer choices to a question, or the movement speed of the objects) in order to decrease/increase its difficulty level, as well as adjusting its interface (e.g. interaction mode, colours, fonts, and/or elements to show). Accordingly, a rule for simplifying a given exercise (e.g. with fewer on-screen elements) and/or showing a tutorial on how to perform the exercise, for instance, could be triggered when the user is not able to finish the exercise after several attempts.

Web technologies and standards have been used to develop our tool because they provide portability and allow the concurrent creation and running of diverse instances of its exercises. This means that a number of users can simultaneously perform these exercises using any device with a web browser installed and wherever they are (with Internet connection). In this way, an important saving in both economic and temporary costs is achieved with respect to the same treatment performed in the therapist’s consultation. Furthermore, VIRTRAEL allows the therapists to help a larger number of patients, regardless of where they live.

### *3.2. Usability principles applied to VIRTRAEL*

We have followed a user-centred design process when developing VIRTRAEL with the aim of making our tool easy to use, intuitive, simple and motivational, as well as usable and accessible for all its users. All these features arose since we always had in mind that our motivation was to develop a tool specially intended for the elderly. The development process that we have followed consists of several phases:

(1) First of all, we analysed the users' characteristics. As seen above, older adults present age-related physical, sensory and cognitive limitations, which are often not considered by designers in the development process of software applications, with the result that these applications are not user friendly. The target users of our tool are older than 65 years. Most of them have never used a computer or tablet device, and therefore they are not familiar with a mouse or a keyboard. They present visual impairments, difficulties with fine motor skills and cognitive decline due to age. Many of them have low literacy skills and a low level of education

because they lived in a post-war period, which has resulted in some cognitive limitations.

(2) Taking into account all the limitations previously analysed, we have tried to make VIRTRAEL usable and accessible by applying a set of usability guidelines and principles oriented to elderly people. The computer-based exercises to train attention, memory, planning and reasoning have been designed considering these guidelines and principles. Due to the goals of the tool, the elderly have to read and watch the screen to perform the exercises, hence VIRTRAEL has not been designed to be accessible for users with severe visual impairment and blindness.

(3) Usable and accessible prototypes of the tool are created, following an iterative development process.

(4) The last phase is devoted to evaluating the prototypes developed by applying different techniques, such as direct observation, thinking aloud, and testing, to discover how the usability of VIRTRAEL can be improved and to check user satisfaction.

Focusing on the second phase (2), we have applied a set of usability guidelines and principles, extracted from a literature review (Arch 2009b; Arch and Abou-Zhara 2008; Becker 2004; Bernard, Liao, and Mills 2001; Campbell 2015; Chadwick-Dias, McNulty, and Tullis 2003; Fisk et al. 2009; Hart, Chaparro, and Halcomb 2008; Kurniawan and Zaphiris 2005; Lynch, Schwerha, and Johanson 2013; Morrell 2005; NIA-NLM 2002; Nielsen 2013; Patsoule and Koutsabasis 2014; Pierotti 2004; Sanner 2004; SF 1999; Zaphiris, Ghiawadwala, and Mughal 2005; Zaphiris, Kurniawan, and Ghiawadwala 2007; Zaphiris, Pfeil, and Xhixho 2009; Zhao 2001). These principles and guidelines can be classified into three categories:

- *Visual design*: This is focused on the user interface aesthetics in order to enhance the tool's usability and the user experience. Visual design guidelines and principles take into account images, typography (fonts and type size, weight, capital letters and spacing), justification, colours, backgrounds, contrast, buttons and icons, labels and layout consistency. Visual design principles include all the visible elements of the user interfaces.

- *Interaction design*: This is responsible for modelling an easy and intuitive interaction between the users (i.e. older adults, in our case) and the application. In other words, this type of design defines how the older adults interact with VIRTRAEL, and how it behaves in response to user actions. Interaction design guidelines and principles involve input devices, navigation elements (such as scrolling, menus, size and position of buttons,…), user adaptation, etc.
- *Information design*: This is aimed at analysing, structuring, organizing and presenting information in a way that makes it easily understood and accessible by older adults. Information design guidelines include language style (user language, direct style, positive sentences, etc.), content structure of the exercises and user support (error and help management).

Regarding our third phase (3), i.e. the creation of usable and accessible prototypes of the tool following an iterative development process, the participation of therapists and elderly people was especially important. A group of 3 psychologists and 4 older people tested the prototypes of the previous version of the tool, called PESCO, and all the versions of VIRTRAEL. Their main suggestions collected to improve them were about the information provided by the character who guides the exercises, and about the layout of the elements on the screen in some exercises. Time and number of repetitions of some exercises were also modified after the test to fit the mean pace of the exercise performance by elderly people and their level of tiredness.

The last phase (4), and more specifically, the evaluation of the last version of VIRTRAEL, is the main focus of this article, since such version is the one used to carry out the study described below.

## 4. Materials and methods

In this section, we will describe the study of usability in which 149 older people that used VIRTRAEL for 13 sessions participated and then completed a usability questionnaire.

### *4.1. Design*

In our study, VIRTRAEL was initially used by 275 users aged between 65 and 91 years. The requirements for being recruited were: being older than 60, able to read text on the screen, able to follow verbal instructions, and cognitively intact or with mild cognitive impairment (MCI). People with dementia or Alzheimer's were not included in the study.

Participants were distributed in groups from 10 to 20 people, according to their proximity to the centre in which they had to use VIRTRAEL. One of the groups was formed by users who used VIRTRAEL from their homes.

The users who wanted to participate in the usability assessment answered a web survey on the usability of the tool. An exploratory experimental factor analysis was performed on the data collected in it.

From the 275 elderly people who used VIRTRAEL, 149 of them responded the survey. Thirty three (33) of them were male and 116 female, and 109 lived alone and 40 with someone else. Information about these and other demographic characteristics of the users is shown in Table A.1, which can be found in the Appendix.

### *4.2. Instruments*

We have used two instruments to carry out our study: VIRTRAEL tool and a specific questionnaire to assess its usability.

Within VIRTRAEL, an initial questionnaire about demographic and personal aspects, such as age, sex, if they live alone or not, education background and performance of ADLs, was completed by the participants during the first session. The data collected in it are used in the data analysis phase.

We have designed the usability questionnaire shown in English in Table A.2 (included in the Appendix), though the original questionnaire is in Spanish. To create it, we have taken into account some of the examined questionnaires existing for elderly people. Although these were designed for this target group, their questions are generic, reason why we have created our own questions, which are more specific and adapted to both our application domain and our target users. As illustrative examples, the question 6 included in the U.S.A.B.I.L.I.T.Y. survey (Caboral-Stevens 2015) is "The website is user friendly”, and the question 7 in the PHWSUQ questionnaire (Nahm, Resnick, and Mills 2006) is “I found the use of this Web site easy to learn”, which are too generic and perhaps difficult to understand and therefore adequately answer by older people. Unlike these, our questions are more specific, as we can check reading for example the questions 15 “Do the instructions explain well how to carry out each exercise?” and 21 “Is the size of the letters adequate?” of our questionnaire, which respectively try to assess cognitive and visual aspects. Question 15 also try to evaluate whether the presentation and organizational structure is well defined. The resulting questionnaire assesses the main dimensions of usability and bears in mind the specific characteristics of the older adults (age-related physical, sensory and cognitive limitations), the context (users not familiar with technology, low literacy skills and a low level of education) and the exercises (with suitable instructions, trial, repetitions and feedback to the user in order to guide the user and facilitate the execution on the exercises). It also considers satisfaction aspects to check whether older people consider the application pleasant, simple and motivating or not.

The usability questionnaire to be completed by the participants is shown in Table A.2 (included in the Appendix). It is made up of 32 items or questions to be answered via a 5-point Likert-type scale. Our questionnaire includes a first group of questions (whose numbers are 9, and 17-26, see Table A.2) to evaluate the ease of use of VIRTRAEL by elderly people (including accessibility, visual and graphic design, and consistency). There is a second group of questions (1-8, 10-16, 27 and 28, consult Table A.2) to evaluate the user interaction with the exercises, as well as if they are easy to understand, perform and remember. This group also includes questions to evaluate the information provided: organization and structure of the exercises, language used, and error management. The last group of questions (29-32, included in Table A.2) considers the context of the participants before and after performing the exercises, the perceived usefulness of the tool and the overall user satisfaction.

The internal consistency reliability of this survey was provided by means of a Cronbach's alpha coefficient. It obtained 0.83, which is considered a very good score. It affects validity of factor loadings that are computed in the factor analysis. Besides, the MSA (Measure of Sampling Adequacy) was obtained, with a value of 0.88. More details of this analysis can be found in Section 4.4.

We think that our questionnaire could be easily used to assess the usability and accessibility of other applications for older adults, especially if the application given consists of a series of exercises which include the relevant instructions, helps and steps to be carried out so that the user can complete them, as well as error management and reinforcements.

### *4.3. Procedure*

The study was conducted in 10 centres from different cities and villages of our province, in Spain. There were from 10 to 20 users in each centre, and 10 more in their homes. Some centres offered more than one turn (morning and afternoon) to participate in the study.

All the 275 participants completed a consent form, approved by our University Ethic Committee. Then, they used a computer or a tablet to perform the exercises included in VIRTRAEL in 13 sessions, taking from 1 to 2 hours per session, depending on the exercises time and on the user abilities and/or state.

During each session in the classroom, one therapist observed the users, took notes about their comments and their difficulties related to the use of VIRTRAEL, and helped them in specific cases.

The 13 sessions constitute the set tasks to be evaluated by completing a survey.

At the end of the last session, 149 users (those who wanted from the 275 initial ones) completed the mentioned survey about usability aspects of our tool. Each participant took 15-30 minutes to complete it, and none of them showed signs of cognitive fatigue while responding. Some of them asked the psychologist attending the session about the meaning of specific questions or to clarify them, but none of them complain about the length of the survey. In addition, as we used a web questionnaire, the users who needed it could enlarge the font size.

### *4.4. Data analysis*

An EFA (Exploratory Factor Analysis) was conducted on a 32-item questionnaire designed to evaluate VIRTRAEL's usability. It was answered by 149 people. The analysis was carried out in R (TRF 2009). Both the code and the data used in this study are supplied as supplemental material and are openly available in the public repository Figshare, so that the analysis can be reproduced if desired.

All the variables have a rank of values between 0 and 4. The descriptive statistics of the variables, i.e. Mean, SD and Median, are shown in Table 1. Just highlight that in all cases, except one, the Median is 3 or 4.

The Bartlett test indicated no correlation matrix singularity, that is, the null hypothesis of an identity matrix was rejected. The determinant of the correlation matrix was positive, so we can extract common shared variance.

The KMO (Kaiser-Meyer-Olkin) test of sampling adequacy was statistically significant, indicating an adequate sample size. Overall MSA (Measure of Sampling Adequacy) was 0.88, this corresponds to the "meritorious" level in the benchmark associated with this test. MSA has also been calculated for each variable, as shown in Table 1, which indicates that sample size is adequate for all the variables.

A screen plot indicated three possible factors. However, by trial and error, we find that a semantically more coherent result is obtained with four factors. Therefore, we have performed the analysis considering four factors. The EFA with principal factor solution method and varimax rotation had the maximum amount of explained variance (47%) similar to other solutions, but in this case, through rotation, the meaning of the factors is clearer.

**Table 1.** Variables' statistics.

| Var. | Mean | SD | Median | MSA |
|---|---|---|---|---|
| P01 | 2.89 | 0.96 | 3 | 0.84 |
| P02 | 3.10 | 0.96 | 3 | 0.91 |
| P03 | 2.57 | 0.83 | 3 | 0.87 |
| P04 | 3.19 | 0.86 | 3 | 0.84 |
| P05 | 2.75 | 0.86 | 3 | 0.86 |
| P06 | 3.40 | 0.86 | 4 | 0.87 |
| P07 | 3.03 | 0.95 | 3 | 0.91 |
| P08 | 2.74 | 1.33 | 3 | 0.72 |
| P09 | 3.35 | 0.88 | 4 | 0.93 |
| P10 | 2.52 | 0.73 | 3 | 0.85 |
| P11 | 2.81 | 1.14 | 3 | 0.78 |
| P12 | 2.64 | 1.26 | 3 | 0.74 |
| P13 | 2.75 | 0.91 | 3 | 0.88 |
| P14 | 3.02 | 0.92 | 3 | 0.88 |
| P15 | 3.19 | 0.93 | 3 | 0.92 |
| P16 | 2.07 | 0.85 | 2 | 0.92 |
| P17 | 2.89 | 0.92 | 3 | 0.92 |
| P18 | 3.37 | 0.84 | 4 | 0.92 |
| P19 | 3.72 | 0.64 | 4 | 0.89 |
| P20 | 3.59 | 0.75 | 4 | 0.91 |
| P21 | 3.56 | 0.70 | 4 | 0.92 |
| P22 | 3.33 | 0.97 | 4 | 0.91 |
| P23 | 3.39 | 0.82 | 4 | 0.92 |
| P24 | 3.49 | 0.75 | 4 | 0.92 |
| P25 | 3.52 | 0.78 | 4 | 0.92 |
| P26 | 3.52 | 0.80 | 4 | 0.95 |
| P27 | 2.65 | 1.26 | 3 | 0.82 |
| P28 | 3.17 | 0.91 | 3 | 0.89 |
| P29 | 3.39 | 0.83 | 4 | 0.86 |
| P30 | 3.37 | 0.90 | 4 | 0.83 |
| P31 | 3.80 | 0.52 | 4 | 0.86 |
| P32 | 3.59 | 0.69 | 4 | 0.70 |

In Table 2, factor analysis is represented, factor and variables are related and factor loadings are also shown.

**Table 2.** Factor Analysis.

| Var. | Question | Loading | Factor |
|---|---|---|---|
| P21 | Is the size of the letters adequate? | 0.76 | PA1 |
| P19 | Can you distinguish clearly the colours on the screen? | 0.74 | |
| P26 | Is it easy to click on a button? | 0.71 | |
| P25 | Is the size of the buttons appropriate for clicking on them? | 0.65 | |
| P24 | Is the size of the images included in the exercises suitable? | 0.62 | |
| P09 | Do you have enough time to read the instructions? | 0.61 | |
| P20 | Do you distinguish the colours of the letters in the explanations (instructions)? | 0.58 | |
| P23 | Do you distinguish the images that appear in the exercises? | 0.57 | |
| P22 | Can you easily read the type of the letter? | 0.55 | |
| P18 | Are the buttons visible when you need them? | 0.49 | |
| P06 | Do you know the meaning of the gold, silver and bronze medals? | 0.46 | |
| P17 | Is the place of the instructions (explanations) and buttons on the screen the same or similar in all the exercises? | 0.40 | |
| P05 | Do you always know what you are doing or what is happening in the exercise? | 0.64 | PA2 |
| P10 | Do you know how to carry out the exercises? | 0.62 | |
| P03 | Do you understand the correct solutions to some exercises? | 0.59 | |
| P01 | Do you know what exercise is being carried out at every moment? | 0.58 | |
| P16 | When the instructions are complicated, are you able to remember them afterwards? | 0.57 | |
| P13 | Do you know the instructions of the exercises? | 0.56 | |
| P02 | Do you know when the instructions end and a new exercise begins? | 0.53 | |
| P14 | Do you know all the words that appear in the instructions? | 0.52 | |
| P07 | Do you know what the buttons are for in the exercises? | 0.46 | |
| P08 | Can you begin the exercise when you want? | 0.42 | |
| P11 | Are you notified when you make mistakes when performing the exercises? | 0.70 | PA3 |
| P28 | Do you think that you have enough instructions to carry out the exercises? | 0.63 | |
| P12 | If an error message is shown, does it indicate how to solve it? | 0.58 | |
| P04 | Are the steps to carry out the exercises explained well? | 0.56 | |
| P27 | In the case that you do not remember the instructions, can you get access again to read them? | 0.52 | |
| P15 | Do the instructions explain well how to carry out each exercise? | 0.46 | |
| P30 | Every day, after carrying out the exercises, do you feel good? | 0.62 | PA4 |
| P29 | Every day, before carrying out the exercises, do you feel good? | 0.55 | |
| P31 | Did you like participating in this project? | 0.53 | |
| P32 | Do you think that stimulating your brain activity has been useful? | 0.42 | |

The first factor (PA1) is related to *Visual Design Quality*, the second one (PA2) with *Interaction Quality*, PA3 with *Information Design Quality*, and PA4 with *Satisfaction*. Hence, VIRTRAEL's *Usability* and *Accessibility* have been decomposed into these 4 factors.

To assess the goodness of our factorial solution, we have obtained the RMSR (Root Mean Square of Residuals) indicator, with a value of 0.0477. RMSR values less than 0.08 are considered adequate.

For each user, we have collected his/her personal profile data. After a study of the relevance of these data using Data Mining techniques through Microsoft SQL Server, we have determined that the most relevant personal profile data are the gender and the fact of living or not living alone. Consequently, we have considered two classification variables: *Gender* and *Alone*.

In Table 3, averages of the variables that make up each factor by the value of the classification variable are presented.

**Table 3**. Averages of the variables by factor and classification variable values.

| Variable | Value | PA1 | PA2 | PA3 | PA4 |
|---|---|---|---|---|---|
| Gender | F | 3.39 | 2.66 | 2.89 | 3.55 |
| | M | 3.54 | 3.06 | 3.14 | 3.49 |
| Alone | N | 3.41 | 2.76 | 2.86 | 3.50 |
| | Y | 3.47 | 2.72 | 3.16 | 3.65 |
| All | | 3.43 | 2.75 | 2.94 | 3.54 |

The greatest differences in the factors are given for PA2 and PA3 considering the *Gender*, and for PA3 and PA4 with respect to *Alone*. Fig. 8 and Fig. 9 show a representation of the factorial scores for the factors with greatest differences and the average of the values of the classification variables. For each factor, its percentage of representability is shown in parentheses (on the axes).

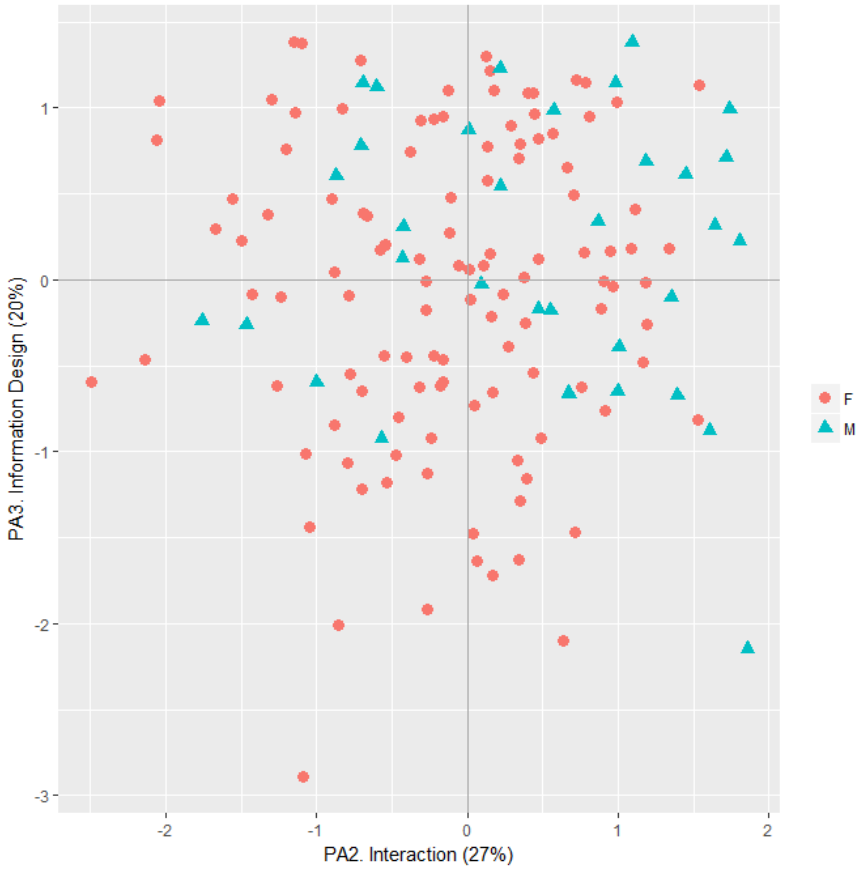


**Fig. 8.** Factorial scores for PA2 and PA3 factors, according to the *Gender* variable.

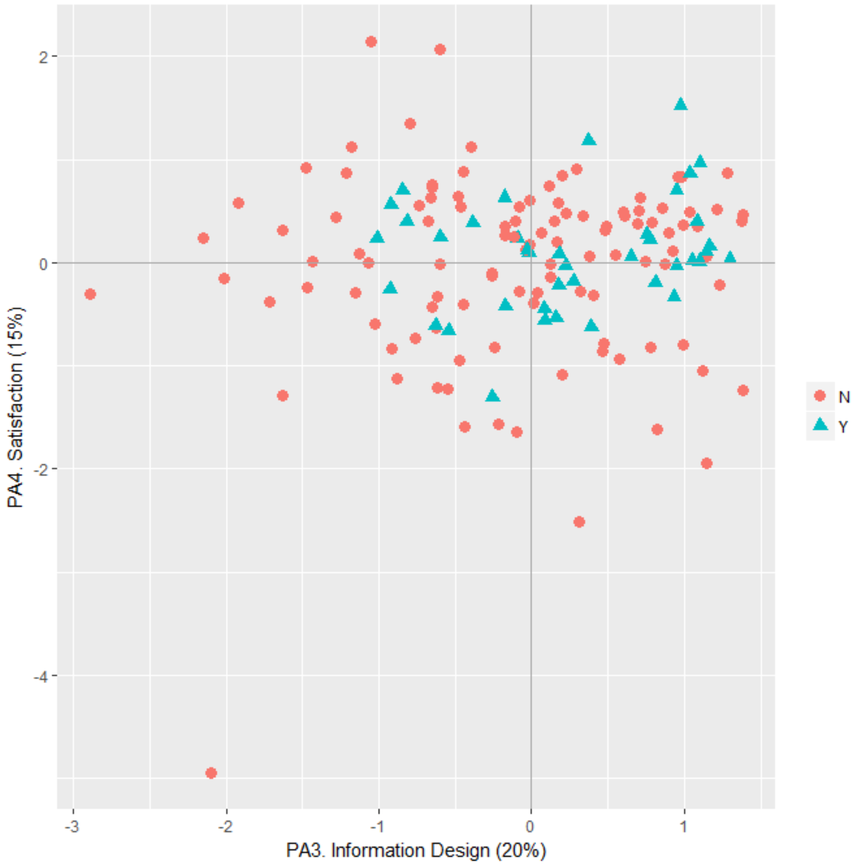


**Fig. 9.** Factorial scores for PA3 and PA4 factors, according to the *Alone* variable.

Moreover, as can be observed in Fig. 9, there is also a small difference in Information Design and Satisfaction between people who live alone (Y) and those who do not (N). People who live alone are less scattered.

## 5. Results and discussion

During the test, we ensured that the participants were comfortable. It was difficult at the beginning of the sessions to keep them focused because, in general, they like to talk with their partners about their lives and beliefs. Nevertheless, it was useful to know how they felt and what they were learning. At the end of each session, they usually shared with their partners and the therapist the results of their performance, medals obtained, difficulties found and feelings. In general, they were satisfied with VIRTRAEL and reported only minor problems regarding its usability in the first sessions, which is in line with the responses provided in the usability survey.

As we stated before, several usability guidelines specifically intended for elderly people were considered in the development of VIRTRAEL. For example, using a larger font size to overcome the sensory decline associated with the loss of vision; including a virtual assistant to guide the user in the performance of the exercises, thus decreasing the cognitive burden and the consequent disorientation; and providing big buttons and a responsive user graphical interface to facilitate that the elderly people with certain physical problems can easily interact with our tool.

In this study, we wanted to test if users perceived such usability aspects and consequently evaluate if our effort to include them in VIRTRAEL was effective.

The method EFA has provided a grouping of 4 factors, which corresponds with the logical grouping of questions in the survey, according to the main aspects that influence accessibility: Visual Design Quality, Interaction Quality, Information Design Quality, and user Satisfaction. All these factors have a high mean close to 3 or higher (out of 4). This means that in a scale of low/medium/high usability, our tool would have a medium/high usability. This confirms that users perceive that VIRTRAEL is usable.

The lower value is for the PA2 factor, Interaction Quality. Regarding specific questions, the lowest value corresponds to question P16, about remembering instructions. In some exercises, the users requested the help of the therapist because they were not able to remember all the instructions or guidelines for performing the exercise. Taking into account this aspect and the suggestions of the elders, we have added a link to instructions that can be read again when the user wants while performing the exercise. Question 31 (Did you like participating in this project?) got the higher value, which shows that participants' satisfaction is high. The questions related to Visual Design, factor PA1, had the higher values. As VIRTRAEL has been designed taking into account the characteristics of elderly users, these values confirm that we have achieved our purpose of creating an intuitive user interface that is easy to use.

Fig. 8 also shows a significant difference between the answers of male and female participants in Interaction Quality and Information Design Quality questions. It may be due to women showing a lower performance than men in attention and working memory (WM) in the pre-test carried out in this study [Attention: $\bar{x}_{women}$=6.33; $\bar{x}_{men}$=8.20 ($t$=-4.008, $p\leq0.001$); WM: $\bar{x}_{women}$=5.66; $\bar{x}_{men}$=7.60 ($t$=-5.074, $p\leq0.001$)]. This type of memory allows the storage of information and its processing for a short period of time to perform more complex tasks (Baddeley 1992), such as reading comprehension, learning and reasoning. Lower scores in WM and attention may lead women to need more time to read the instructions and the alternative responses to the exercises. In fact, in a lot of cases, they needed to ask for help from the therapist in the classroom. The participants in our study are a homogeneous group at educational level due to they represent the real proportion regarding education of the Spanish population in the age range considered. It was difficult to get a higher education level during their youth due to the post-war, especially for women, with less access to education in that period.

It is also important to highlight that this was their first time in using a computer or tablet for 39% of the participants. If we add to this that, even having their own computer around, 5.8% of them do not know how to use it, the utilization rates are very low (from 7.6 –e-mailing/texting– to 44% –contacting medical providers–) and men are more likely to access ICTs than women (Kim et al. 2017), it is understandable that they needed more help to know how to interact and the dynamics of the exercises in the first sessions.

In this study, most of the participants used a PC, but some of them with difficulties to use the mouse and keyboard used a tablet device with touch screen. Software setups were the same in all the devices. We have not observed differences in the usability perceived by the participants depending on the device they used.

Regarding the difference in the answers provided by participants who live alone or not, we could justify higher values for those who live alone because they are more self-sufficient or independent and have less cognitive impairment. Recent studies (Mazzuco et al. 2017; Murayama, Fujiwara, and Kawachi 2012) have reported that, in the case of the elderly, living with others implies a greater decline in some abilities and the older adults who live alone have higher functional and cognitive levels. Living alone probably encourages the retention of functional and cognitive ability among the elderly basically because they have to do things for themselves in everyday life. This explains that participants who live alone have fewer problems to read and understand instructions by themselves and to act in an independent way.

A limitation of this study is the non-homogeneous distribution of the participants regarding their gender and if they live alone or not.

## 6. Conclusions and future work

The main contributions of this paper are: (1) The creation of a guide including design principles and usability guidelines for the development of software tools to be used by older people; (2) The application of the mentioned guide to the development of a web-based tool to cognitively assess and train the elderly, named VIRTRAEL, which have been described, and we have also explained why it is usable; (3) The creation of a usability questionnaire to be completed by elderly people, taking into account their characteristics and the VIRTRAEL tool to be evaluated, and (4) The presentation of the significant results obtained from a study carried out with a high participation (149 subjects). We sincerely think that both the design guide and the usability questionnaire provided can be easily applied to respectively develop other software applications for this user group and evaluate them.

During the development of VIRTRAEL, we considered that, in order to be able to produce an effective cognitive stimulation, a high degree of usability was to be reached. That goal made it necessary to apply a user-centred development methodology and a set of usability principles and guidelines to design the set of 18 exercises that are currently available in VIRTRAEL.

The proposal has been tested with 149 subjects, who have also filled in a 32-item usability questionnaire. An EFA (Exploratory Factor Analysis) has been conducted, confirming that the users consider VIRTRAEL as a usable tool. In addition, we found two important results:

- Female participants generally considered the interactive tasks more difficult to perform than male participants.
- Participants who live alone had a more favourable opinion regarding the usability of VIRTRAEL than participants living with other people.

These differences are explained by the distinct degree of independence and ICT skills that these user groups may have. Nonetheless, they highlight that adapting software to user profiles is a necessity, and consequently a high usability level must be reached. Additionally, they demonstrate that user profiles must encompass background information about the user to achieve an effective adaptation.

As for future work, we plan to introduce adaptations for very specific user groups into the design guidelines and usability principles that we have applied. Consequently, we will re-implement some exercises of VIRTRAEL (particularly, the most interactive ones) to achieve an even higher usability level. Our final objective is to personalise the exercises included in VIRTRAEL. To do so, we need to define user profiles and adapt our application taking into account the information stored in such profiles in order to better fit the tool usability to each individual.

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## Disclosure of interest

The authors report no conflict of interest.

## Data availability

Both the data that support the findings of this study and the code (written in R) used to analyse them are supplied as supplemental material (when submitting the manuscript) and will be openly available in the public repository Figshare.

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# Appendix

**Table A.1.** Demographic statistics of the pilot sample.

| **Demographics** | **Frequencies** |
|---|---|
| *Gender* | |
| Males | 33 (22.15%) |
| Females | 116 (77.85 %) |
| *Age* | 65 – 91 |
| *Live* | |
| Alone | 109 (73.16%) |
| With somebody else | 40 (26.84%) |
| *Education background* | |
| 1 Read/write | |
| 2 Some years in elementary school | |
| 3 Graduated elementary school | Mean: 2.32; SD: 1.71 |
| 4 Graduated high school | Mean men: 3.30; SD: 2.26 |
| 5 Diploma | Mean women: 2.03; SD: 1.41 |
| 6 Associate Degree | |
| 7 Graduated College | |
| 8 Advances Degrees | |
| *Computer expertise* | |
| Novice | 38 (29.53%) |
| Beginner | 111 (70.47%) |
| Expert | 0 (0%) |

**Table A.2.** Usability questionnaire completed by the participants in the survey.

| Code | Question |
|---|---|
| P01 | Do you know what exercise is being carried out at every moment? |
| P02 | Do you know when the instructions end and a new exercise begins? |
| P03 | Do you understand the correct solutions to some exercises? |
| P04 | Are the steps to carry out the exercises explained well? |
| P05 | Do you always know what you are doing or what is happening in the exercise? |
| P06 | Do you know the meaning of the gold, silver and bronze medals? |
| P07 | Do you know what the buttons are for in the exercises? |
| P08 | Can you begin the exercise when you want? |
| P09 | Do you have enough time to read the instructions? |
| P10 | Do you know how to carry out the exercises? |
| P11 | Are you notified when you make mistakes when performing the exercises? |
| P12 | If an error message is shown, does it indicate how to solve it? |
| P13 | Do you know the instructions of the exercises? |
| P14 | Do you know all the words that appear in the instructions? |
| P15 | Do the instructions explain well how to carry out each exercise? |
| P16 | When the instructions are complicated, are you able to remember them afterwards? |
| P17 | Is the place of the instructions (explanations) and buttons on the screen the same or similar in all the exercises? |
| P18 | Are the buttons visible when you need them? |
| P19 | Can you distinguish clearly the colours on the screen? |
| P20 | Do you distinguish the colours of the letters in the explanations (instructions)? |
| P21 | Is the size of the letters adequate? |
| P22 | Can you easily read the type of the letter? |
| P23 | Do you distinguish the images that appear in the exercises? |
| P24 | Is the size of the images included in the exercises suitable? |
| P25 | Is the size of the buttons appropriate for clicking on them? |
| P26 | Is it easy to click on a button? |
| P27 | In the case that you do not remember the instructions, can you get access again to read them? |
| P28 | Do you think that you have enough instructions to carry out the exercises? |
| P29 | Every day, before carrying out the exercises, do you feel good? |
| P30 | Every day, after carrying out the exercises, do you feel good? |
| P31 | Did you like participating in this project? |
| P32 | Do you think that stimulating your brain activity has been useful? |

List of available answers for questions from P01 to P28:

4- Always 3- Almost always 2- Sometimes 1- Hardly ever 0- Never

List of available answers for questions from P29 to P32:

4- A lot, it has been great! 3- A large extent 2- Normal 1- Barely 0- Not at all