Abstract—This paper presents a game that is integrated into a computer-based training program for several cognitive tasks in the elderly. People with Age-Associated Cognitive Decline (AACD) and people with Mild Cognitive Impairment (MCI) are its target population. The game, which is specially intended to improve or maintain executive functioning, requests users to buy some gifts to some imaginary close relatives, taking into account a budget that should not be exceeded and some specified criteria about their preferences. The aim is the training of users’ planning ability, as well as the needed organization to achieve the planned goals. In addition to give details of the design and implementation of this game, the paper presents its validation, using standardized neuropsychological measures. To do that, an experimental pilot study has been carried out with 20 people over 60 years. Once the game has been validated, more people are using it.

Keywords—cognitive stimulation; computer-based training; executive functions; planning ability; age-associated cognitive decline; mild cognitive impairment; elderly

I. INTRODUCTION

In most countries, demographic developments tend towards an increasing number of older people living in single households. Improving their quality of life is therefore an emerging issue within our information society. Computer applications could offer these users benefits in physical, medical, emotional, motivational or educational aspects.

Daily, it is recommended for elderly: planning physical exercise (walking, lawn bowling, etc.), reading, maintaining the household responsibilities, attending social events (taking part in conversation, dancing, etc.), learning new things (using a computer, gardening, cooking, etc.) and playing games (cards, domino, bingo, memory and matching). These activities help to alleviate feelings of isolation and loneliness, preventing the depression. It is very important for all the older people regardless of age and physical or mental abilities to stay active (keeping up or improving their physical and mental conditions).

In this sense, the concept of cognitive impairment intervening between normal ageing and very early dementia has been treated in the literature for many years. On this transitional zone, several terms has been used such as ‘age-associated cognitive decline’ (AACD) [1] and mild cognitive impairment (MCI) [2]. In a cognitive continuum, the MCI overlap on both ends indicating that the distinction between normal ageing (i.e. AACD) and MCI can be quite subtle and, in addition, the specific transition between MCI and very early dementia can also be challenging. The concept of MCI refers to a group of individuals who have some cognitive impairment but of insufficient severity to constitute dementia. There are several clinical subtypes of MCI: the amnesia type, the multiple domains type, which involves impairment in multiple cognitive domains, and the single non-memory domain type, in which a person has impairment in a single non-memory cognitive domain such as language, executive function or visuospatial skills [2]. Besides the well known amnesia impairment, the executive functioning has played a key role in the cognitive and functional testing and training in healthy and MCI older people. Recent cognitive interventions have been summarized [3] for showing how directed cognitive exercise produced robust and enduring benefits on a general functional outcome that is relevant on delay of dementia onset. Several of those training programs involved executive function activities, such as self-generated strategies [4] and problem-solving [5]. One of the largest studies was a computer-based training on several cognitive tasks [6]. In sum, there are evidences to focus on executive computer-based training games in order to improve or maintain executive functioning in older people. However, the elderly can have problems to access to the technology, due to either age-derived impairments or their lower education levels. The main impairments that they present are the following ones [7][8]:

- **Vision:** reduction of the width of the visual field, as well as their abilities to see fine details and process visual information.
- **Hearing:** reduction of the ability to hear some sounds.
- **Psychomotor skills:** increment of the response times.
- **Attention:** less attention to particular details in the presence of distracting information.
- **Memory:** short-term and working memory worse with age.
- **Learning:** reduction of the ability to learn new things or learn to perform activities in a different way.
II. **Usability and Accessibility Guidelines for the Elderly**

To allow that the broad range of technology begins to be used by older people without fear, it must be more accessible, useful, usable and enjoyable for all. Older people needs must be taken into account in the design process of a computer application to adapt it to them. In this sense, there exist some usability guidelines that provide some design-oriented suggestions for computer applications [8][9][10][11][12]. The most relevant ones are shown in the following subsections, each of them are devoted to a kind of impairment.

### A. Visual Impairment

- Large font sizes, 12 point type at least.
- Let the users increase text size as desired.
- Font type easy to read.
- High contrast between text and background.
- Present clear and simple screens.
- Minimize blinking images and animations.
- Use alternatives of text and sound for multimedia contents with visual information.
- Use big screens. The limited screen space in mobile devices impedes to provide optimized information access.

### B. Hearing Impairment

- Let the users increase volume sound as desired.
- Use alternative multimedia contents (text, image and/or video) to audible information.

### C. Motor Impairment

- Separate the targets for clicking to decrease erroneous clicks and increase the speed to reach and hit the correct link or button.
- Avoid moving interface elements (for example, pull-down menus, new windows and cascading menus) because they require pixel-perfect point and are difficult to be selected with the mouse.
- Add new interaction modes (speech, tactile, adapted devices, ...).
- Avoid the use of mobile devices, because their limited screen size impedes to provide optimized information access.

### D. Cognitive Impairment

- Differentiate the targets to be selected using different color, separating them with lines or highlighting them with a box or painting borders around them.
- Differentiate when a target has been selected or deselected.
- Use short text against lists of text paragraphs.
- Avoid moving interface elements (for example, pull-down menus, new windows, cascading menus and rollover text), because they can disappear from the screen and confuse to the users.
- Avoid using too many different fonts.
• Limit the amount of information on each page and simplify their structure.
• Decrease the functionality of the applications, and provide context and orientation information to decrease users’ cognitive load. Showing information about what actions have been performed and what places of the application have been visited helps users not to feel lost in the application structure, as well as not to perform repeated actions.
• Help to avoid mistakes providing use guidelines for the applications, with examples, trials and demos.
• Facilitate the filling in of electronic forms, including appropriate lists of values and fixed size fields, and validating all the user inputs.
• Avoid delays and distractors to minimize memory loss.
• Provide clear error messages and centered in the own error. In addition, these messages should always be shown at the same place of the screen.
• Give explicit instructions by using the imperative form of verbs.
• Offer reinforcement about the performing of the tasks.
• Use wizards that guide users in the activities to be carried out.
• Use touch-screen interfaces to make easier the interaction with the application. The use of a mouse requires eye-hand coordination and increases the cognitive load.
• Avoid using technical language.
• Do not use innovative technologies that require users’ high skills.

All these guidelines must be applied to software tools for the elderly, and even more to computer-based cognitive stimulation programs.

III. COMPUTER-BASED COGNITIVE STIMULATION PROGRAMS

A. Traditional Versus Computer-Based Psychostimulation Programs

Although there is much knowledge about psychostimulation, a number of aspects make difficult to apply the traditional psychostimulation programs [15] to every person who needs it, including the following ones:

• A very specialized training in neuropsychology is required to provide a good cognitive rehabilitation, applying adequate psychostimulation programs.
• High cost in both human and economic resources, since it requires that the psychotherapist dedicates a considerable amount of time to the patient.
• More difficulties for potential users in smaller towns and rural areas, where the specialists required are scarce, and their programs are usually more expensive.
• Many of the existing psychostimulation programs tend not to take into account the social and cultural environment of the patient.

However, the application of new Information and Communication Technologies (ICTs) to this area has made possible to develop and establish appropriate computer-based psychostimulation programs without significant costs. Some of the advantages that these technologies are providing within the cognitive stimulation scope are the following ones:

• Development of flexible programs that can be easily adapted to the deficit of each user, since the values of different parameters can be selected in function of each patient’s needs. This flexibility increases the use and learning of the program, as well as its usability.
• Increment of the number of therapy hours, since the software support allows the therapist to apply psychostimulation programs to several users at the same time, as well as patients to carry out certain sessions at home.
• More effectiveness of the treatment, thanks to stimulation sessions are shorter (to avoid tiring the patient) and are carried out more often.
• A fast and proper feedback with regard to mistakes and failures.
• Results are registered and can be shown (to the therapist and/or the patient) after each stimulation session. In addition, the values of certain variables of interest (such as exposure time of stimuli and reaction time) are accurately registered for a subsequent analysis.
• Objective access to the results, which improves the analysis and control of patients’ performance evolution.
• Tasks to be performed can be changed in function of each user’s results.
• Different computer interaction devices can be used to adjust to each user’s needs.
• Computer software can motivate the patient, presenting the tasks to be carried out in a more attractive and dynamic manner.
• Therapist’s work is facilitated, streamlining and speeding up the management of the stimulation materials.
• Access to training and information via Internet, which allows therapists and patient’s relatives to increase their expertise in this area and provide a better service and aid to the patient.

B. Review of Software Tools for Cognitive Stimulation

A variety of cognitive intervention techniques have been developed by means of interactive computer programs. The existing programs can be clustered into two blocks, according to their purpose:

• Rehabilitation of specific cognitive processes and skills.
• Training of patients in the main cognitive functions, following an ordered sequence from less to more complex programs.
Moreover, there exists software for the diagnosis (previous to the corresponding rehabilitation or training) and for the evaluation of the treatment carried out.

Since the game presented in this paper is integrated into a computer-based evaluation and training program for several cognitive tasks, we present and analyze other existing software related to it in some way.

We have selected and analyzed the following set of computer programs for cognitive stimulation (including rehabilitation, training, diagnosis and evaluation of cognitive functions): THINKable/DOS [16], which is specially intended for memory cognitive rehabilitation of users with cognitive impairment. RehaCom [17] and PSS CogRehab [18] are cognitive rehabilitation programs (only for problem resolution), the former is for users with brain damage, while the latter is not only for this type of users but also for users with cognitive impairment. Viena Test System (VTS) [19], software for psychological diagnosis of users with cognitive impairment. CogniPlus [20], computer program for cognitive training and rehabilitation. Reedua [21], software for early cognitive stimulation. Training of Cognitive Strategies [22], specially intended for users with attention problems. Smartbrain [23], computer-based cognitive stimulation program for users with age-associated cognitive decline as well as users with dementia. Aktiba-T [24], psychostimulation software for people with mild and moderate dementia. Gradior [25] and Telegradior [26] are two computer-based cognitive evaluation and rehabilitation programs for the elderly. ALZ-Avanza [27], cognitive rehabilitation software for users with Alzheimer. m-AvanTIC [28], computer-based training for certain cognitive skills. Cogknow [29], cognitive stimulation computer program for users with mild dementia. HERMES [30], pervasive computer application that aims at alleviating the elderly decline in both declarative and prospective memory.

The analysis carried out indicates that all of them present considerable limitations. First of all, none makes an integral rehabilitation of patients, taking into account all the neuropsychological areas that may be involved in our target population (the elderly). For example, only two of the analyzed programs (RehaCom [17] and PSS CogRehab [18]) include higher executive functions, but both of them are restricted to the training in problem resolution. Moreover, only two programs serve to assess or diagnose the patients, in addition to its rehabilitator purpose.

The most important restriction in this kind of software is the lack of empirical evidence on its effectiveness. In many occasions, cognitive intervention programs are not rigorously and systematically applied [31]. Furthermore, they lack the integration of many aspects that could be very useful for user’s activities of daily life, being this one of the areas that these programs pretend to improve and that unfortunately are often forgotten.

In fact, none of the reviewed programs includes both neuropsychological areas to be rehabilitated and the training in instrumental activities directly involved in the activities of daily life. This could be the reason why in both clinical and scientific practice, these computer programs are often considered as not effective or only temporarily effective.

From all the programs considered, only two have presented data supporting their use to the scientific community. Consequently, we cannot rule out that the rest simply are mere tools of entertainment for our elders. THINKable/DOS have been the first program of its kind that has proven its effectiveness for both people with Alzheimer [16] and people with serious cognitive impairment [32]. The software Gradior has also proven to be effective for patients with mild dementia of Alzheimer type, improving significantly their emotional and behavioural areas, and keeping their cognitive abilities and activities of daily life in comparison with a control group [25].

All the computer programs studied have a commercial license, that is to say, users have to pay for use them. This constitutes other important restrictions, and it is the reason why very few people have access to them. Moreover, they do not tend to focus on normal Age-Associated Cognitive Decline (AACD). Smartbrain [23] is an exception to this point.

Finally, these applications offer a set of static exercises or tests, which are not adaptable to users’ culture, interests and specific needs, although some of them allow to set up the difficulty level of the tests.

In short, there is not yet any computer program that allows evaluating and rehabilitating all the neuropsychological domains affected in the elderly, which is accessible to a wide population, and that has proved its usefulness to prevent progression of age-associated cognitive decline. The aim of PESCO (Programa de Estimulación Cognitiva, Spanish expression for “Cognitive Stimulation Program”), which is the computer-based training program which includes the game presented in this paper, is to cover this gap. PESCO is open source software that can be freely used.

IV. GAME OF GIFTS PURCHASE

A. User Interfaces and Game Description

This game is specially intended to improve or maintain executive functioning, which comprises abilities to generate goals and plans, maintain focus and motivation to follow through goals, follow the rules and make change in response to contingencies. Executive functions enable to generate, maintain, and shift mental sets. Several health conditions associated to age deteriorate executive functions [33].

Taking into account the usability guidelines recommended for the elderly, we have developed a computer-based game to evaluate and training the planning ability, as well as their organization capacity for achieving the planned goals, as indicated in the initial screen of the game (shown in Fig. 1). To do this, users are requested to buy some gifts to some imaginary close relatives, taking into account a budget that should not be exceed and some specified criteria about their preferences.
Before the game starts, several screens explaining all the details of its functioning will be shown to the user. These screens will have a similar aspect to the one in Fig. 1.

Once all the game functioning has been explained to the user, a list of people and their respective preferences (like the one shown in Fig. 2) is displayed. The user must buy a present for each of them, taking into account their preferences when selecting their gifts. Since this is not a memory game, the user does not have to memorize the list. At any time during the exercise, the user can consult this list by clicking the button See list of people and their preferences (placed in the upper left side of the screen, see Fig. 2).

To let the user know the money s/he has spent and the available budget that should not be exceeded, both amounts are shown at the upper right corner of the windows at any time during the game execution (see Fig. 2).

To make purchases, a number of shops will be displayed (see Fig. 3). To see what products can be bought in each of them, the user must click on the shop s/he wants. Then, a screen like the one in Fig. 4 will be displayed, showing an image, a bit description and the price for each product that can be purchased in that shop. When the user selects one of these products, s/he will be asked if s/he wishes to buy it. If the user confirms the purchase, the amount of money spent that appears at the upper right corner of the window is updated.

In a shop, the user can buy as many items as s/he wants. When the user wants to go to another shop to keep buying gifts, s/he must press the button Go to shops, which is placed at the bottom side of the window (see Fig. 4).

If the money spent exceeds the budget assigned, this quantity will be shown in red at the upper right corner of the windows (as shown in Fig. 5). Whenever the user wants, s/he can take items purchased back by clicking on it. Then, a dialog box will be displayed that requests user confirmation (see Fig. 5).

At any time, the user can check what are the items purchased so far by clicking the button Show my shopping (located at the central part of the upper row of buttons, see e.g. Fig. 5). When the user wants to finish the game, because s/he thinks all the gifts have already been purchased, s/he must select the button Finish my purchase (at the right of the upper row of buttons, see e.g. Fig. 5).

Finally, a screen similar to the one shown in Fig. 6 is displayed. Its purpose is to give a feedback to the user, using an intuitive simile, consisting of obtaining either a gold, silver or bronze medal, depending on the performance level reached during the execution of the game.
B. Design and Implementation Details

1) Game elements. In this game, the following elements intervene:

- **Criteria.** A list of criteria (like the ones shown in Fig. 2) is presented to the user. Each criterion, which consists of an imaginary person (friend or relative) and his/her preferences, gives the user the needed information to properly choose a gift for that person.
- **Shops.** Places where the user must buy the gifts.
- **Items.** Objects or products to be sold in a shop. Each item is described by *internal tags*, which are used to select the items to be placed in a shop in each play.
- **Gifts.** Items that the user must buy considering people’s preferences expressed in the criteria.
- **Budget.** Amount of available money for buying all the gifts.
- **Levels.** There are three difficulty levels. Depending on the game level, a different number of criteria (4 in the first level, 6 in the second, and 9 in the third) and shops (with 6, 12 and 15 shops shown in each level) are generated.

2) Each play is different. In each execution of the game, the above elements are randomly selected and combined in order not to present twice the same setting to the user. These are the main aspects considered in the generation process of a new play:

- The game starts at the low difficulty level. This level is increased to the next one when the user obtains a gold medal.
- The criteria are randomly chosen, but taken into account that each criterion (of a specific play) must make reference to an item of a different shop. Thus, if the gift targeted by a given criterion is, for example, a basketball, other criteria related to items of the sport shop are eliminated from the list of available criteria when this criterion is selected.
- Each selected criterion determines a shop to be shown. The rest of shops to complete the number required by a given level (e.g. at level 1, the 4 criteria are used for selecting 4 shops, but 6 shops have to be shown) are randomly chosen and added.
- Proper items are selected and placed in each shop. For each gift pointed out by a given criterion, two prices (one cheap and the other expensive) are randomly generated. This gift will be duplicated in the shop, assigning to each copy one of these prices. The other items to be placed in a shop (up to 9) are chosen according to the similarity with the gift included in it. The similarity calculation is performed using the internal tags that describe each item, by dividing the number of matching tags by the total number of tags (e.g. the item *basketball*, which has the tags "ball" and "basket", has a similarity factor of 0.5 with the item *soccer ball*, which has the labels "ball" and "soccer"). The higher tags matching, the greater the similarity is (e.g. *basketball* has similarity 0 with a *red bicycle*, with "bike" and "red" as its tags).
- The available budget is calculated to be the first multiple of 50 which exceeds the sum of cheaper prices of all the gifts pointed out by the criteria (e.g. if the cheaper options for all the gifts represent a total cost of 215€, the budget will be 250€).

3) Implementation details. The game has been developed using the C# programming language, MonoDevelop programming environment, and Suse Linux operating system. The user interface has been developed using GTK#. The end user trials have been done with the operating system Guadalinex, a special version of Ubuntu.

The game has been implemented as open source software, distributed under a EUPL license. The images used in the game have been obtained from the webs ARASAAC [34] and Aumentativa 2.0 [35].

The data and results generated by the program are stored in XML files. The recovery of these files via Internet is done using an Apache web server and a MySQL database.

C. Registering of Measures and Displaying of Results

1) Data registration. For each execution of the game, the following data are stored:

- Selected criteria.
- Ideal shopping (list of gifts targeted by the criteria).
- Gifts purchased by the user.
- Number of correct and incorrect purchased gifts.
- Total available budget for the user.
- Money spent by the user.
- Used time.
- Degree of similarity achieved (between what user did and what s/he should do).

2) Exercise evaluation. Each play (i.e. game run) is evaluated according to the degree of similarity achieved. This data gives us a number which is calculated by adding the similarities of the items that the user has purchased and dividing this sum by the total number of gifts to buy. In the ideal case (all the purchased items are the correct gifts), the degree of similarity is equal to 1.

In order to give a feedback to the user, a bronze, silver or gold medal will be shown (see Fig. 6). If the degree of
similarity is greater than 0.8, a gold medal will be shown. If the degree is between 0.5 and 0.8, a silver medal will be displayed. Below 0.5, a bronze medal will be shown.

If the user gets a degree of similarity greater than 0.8 and the last game level has not been achieved yet, the level is increased. As mentioned above, a level rising leads to an increase of criteria and shops in the next play.

V. EXPERIMENTAL PILOT STUDY FOR VALIDATING THE GAME

A validation study was carried out using correlational methodology. In order to examine executive function components on the game, scores were correlated with two standardized measures of executive functioning using the Pearson's coefficient ($r$). The Modified Six Elements Test and the Dysexecutive Questionnaire were applied as executive measures. Both are included in the Behavioural Assessment of Dysexecutive Syndrome (BADS) [36]. The Pearson's correlation coefficient reflects the degree of linear relationship between two variables. It ranges from +1 to -1.

A. Participants

Twenty individuals (11 women and 9 men) volunteered to participate in this study. Age range was 59-79 years (mean=65.8; SD=5.6), education range was 1-15 years (mean=5.3; SD=3.5) and time per week using the computer range was 0-14 hours (mean= 3.1; SD= 4.4). All were classified as independent for Daily Living Activities with the Lawton and Brody scale.

B. Instruments

The Modified Six Elements Test (MSET) [36] consists of three types of tests (simple arithmetic, written picture naming, and dictation), each of which has two sub-tasks (thus constituting a total of six sub-tasks). Participants were required to attempt at least part of each of the six sub-tasks within 10 min, following the rule that they are not allowed to switch directly from a sub-task of one type to its counterpart of the same type. To achieve good performance on this test, testees are thus required to mobilize the most appropriate schemata across the different sub-tasks consistently and optimally. They are penalized if they remain more than 271 seconds in a single subtask.

The Dysexecutive Questionnaire (DEX) [36] is a rating report of behavioral difficulties associated with executive functioning. Participants were requested to rate 20 items about their behavioral difficulties commonly associated with dysexecutive functioning. Five factors-scores were used as dependent measures (inhibition, intentionality, executive memory, positive and negative affect) [37].

Participant’s performance on the first difficulty level of the game was used as dependent variables of study. Main raw scores were selected using the following variables: (1) number of correct and (2) incorrect gifts purchased (depending on their coincidence degree with the criteria), (3) time used on the completion (in seconds) and (4) percentage spent of the budget.

C. Results

The main scores got with the game, the MSET and the DEX are shown in Table I. The Pearson's correlation coefficient between number of correct gifts on the game and number of attempted subtasks on the MSET was 0.457 and the association was significant ($p=0.032$). Also a negative correlation was found between time on the completion of the game and the Executive Memory factor of the DEX ($r=-0.456$, $p=0.038$). With this sample, we have a high 95% confidence of avoiding type I errors (finding a correlation that really does not exist in the general population) and a moderate 67% confidence of not committing type II errors (no finding a correlation that actually exists in the general population) [38]. In addition, there was not association between time per week using the computer and performance on the game. Thus, when a person performs better on a multitask measure, such as the MSET plan, s/he achieves more goals in the computer-based game of gifts purchase. And the opposite, when a person shows executive memory problems on daily living activities, s/he takes more time for the completion of the game. These associations indicate that the game shares some key components with the standardized and world-wide measures of executive functioning applied. In spite the correlations are not strong, they constitute significant associations between a computer task and (1) paper-and-pencil and (2) real-world functioning. These findings are relevant for a game in order to train a specific cognitive domain and not to give general stimulation. The absence of significant correlation between users’ ability in the computer use and their performance in the game indicates that its design and interaction are suitable for training executive skills regardless of user's familiarity with the computer.

VI. CONCLUSIONS

We have presented a computer-based game for the cognitive stimulation of executive functions, and more specifically, its aims are the planning ability and the organization capacity for achieving the planned goals.

The game involves executive components, and then can be used for older people training in these specific and relevant elements on the Age-Associated Cognitive Decline (Aacd) or Mild Cognitive Impairment (McI).

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<th>Time used</th>
<th>Correct items</th>
<th>Incorrect items</th>
<th>Percentage spent</th>
<th>Percentage spent</th>
<th>Inhibition</th>
<th>Intentionality</th>
<th>Executive memory</th>
<th>Positive affect</th>
<th>Negative affect</th>
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A pilot study has been carried out to prove its scientific validation. Furthermore, users have been requested to fill in a questionnaire for evaluating their satisfaction by using the game. Analysing the collected data, we can conclude that they have enjoyed and felt motivated and cognitively stimulated. We think that the game design adapted to the elderly (in aspects such as usability and accessibility) has contributed to these results.

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