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An approach to cognitive evaluation using games on TV

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Introduction: The recent advances in consumer electronics paved the way for new approaches to neurophysiological evaluation at home. More specifically, the computing capabilities of state-of-the-art television sets and media centres facilitate the introduction of computer-assisted evaluation at home. This approach helps to overcome the drawbacks of traditional pen-and-paper evaluations administered in clinical facilities, as they can be performed in a more comfortable environment, the subject's home, and they are more flexible to elaborate complex environments for the evaluation of neuropsychological constructs that are difficult to evaluate through traditional testing. The objective of this work was to develop a collection of games to be played on the TV to obtain some initial evidence about the convenience of this approach for the cognitive evaluation of senior adults.

Materials and methods: We developed a collection of games to be deployed on a smart TV environment. These games were tried by a group of senior adults at their homes. Perception surveys were performed to study their usability and acceptability as a means for cognitive evaluation.

Results: More than 90% perceive cognitive games on TV as easy or very easy to interact with, and this result correlates with the number of participants perceiving them as usable or very usable.

Limitations: Although participating users were carefully selected to obtain a representative sample of the Galician population. A larger and more diverse user sample may be needed to obtain significant results for a wider population profile.

Conclusion: The study confirmed the usability and acceptance of games as a means of cognitive evaluation. Nevertheless, more research is needed in order to implement serious games in a way that they are widely accepted by the medical community as a valid, reliable way to perform cognitive evaluation at home.

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Abstract

Introduction: The recent advances in consumer electronics paved the way for new approaches to neurophysiological evaluation at home. More specifically, the computing capabilities of state-of-the-art television sets and media centres facilitate the introduction of computer-assisted evaluation at home. This approach helps to overcome the drawbacks of traditional pen-and-paper evaluations administered in clinical facilities, as they can be performed in a more comfortable environment, the subject's home, and they are more flexible to elaborate complex environments for the evaluation of neuropsychological constructs that are difficult to evaluate through traditional testing. The objective of this work was to obtain some initial evidence about the convenience of using serious games played at home on the TV set for the cognitive evaluation of senior adults.

Materials and methods: We developed a collection of games to be deployed on a smart TV environment. These games were tried by a group of senior adults at their homes. Perception surveys were performed to study their usability and acceptability as an instrument for cognitive evaluation.

Results: More than 90% of participating subjects perceive cognitive games on TV as convenient or very convenient, and this result correlates with the number of participants perceiving them as usable or very usable.

Limitations: Although participating users were carefully selected to obtain a representative sample of the Galician population, which in turn is comparable to the population of any other rural area in Europe, a larger and more diverse user sample may be needed to obtain significant results for a wider population profile.

Conclusion: The study confirmed the usability and acceptance of games as a means of cognitive evaluation. Nevertheless, more research is needed in order to implement serious games in a way that they are widely accepted by the medical community as a valid, reliable way to perform cognitive evaluation at home.

Introduction

Neuropsychological evaluation consists on the study of a subject's performance in a given neuropsychological domain to detect dysfunctions or impairments. Evaluation techniques and protocols have been defined and implemented for domains such as visuospatial abilities, motor coordination, language use, attention and concentration, executive functions or memory. Neuropsychological evaluation is commonly used as a screening technique to detect cognitive

impairments in senior adults [1][2]. Another common subject group for cognitive assessment are students (e.g., as a screening technique to detect relatively common conditions such as dyslexia and attention-deficit hyperactivity disorder[3]).

Typically, neuropsychological evaluations take place in a controlled environment, usually in a clinical facility, and are conducted by health professionals. The tools used consist of a collection of validated neuropsychological pen-and-paper tests[4][5]. The process consists on a face-to-face interview of variable duration, depending on the characteristics of the test suite, along with a guided data collection process, and these instruments produce results in the form of a mark in scale providing an indication of the state of a person in relation to the target neuropsychological domain.

These tests may have limitations that may compromise the reliability of results obtained. For example, testing time may have an impact on the results, as it may affect the neuropsychological status of the subject. However, in most cases the total time needed cannot be foreseen, but depends on the complexity of the test suite and the personal characteristics of the subject. In addition, in many cases testing sessions are perceived as intrusive and unnatural, and as a consequence motivation, attention, alertness, and stress are aspects that may dramatically influence the results. Other important source of bias is the lack of ecological validity [6], that is, the lack of correlation of test items with actual activities of daily living. Finally, many existing test suites may not be valid for low-education or illiterate populations [7].

Games, and more specifically computer games, may not have enjoyment, entertainment or fun as their primary purpose [8]. Games have been introduced in many application areas beyond entertainment such as education [9], rehabilitation [10] or military training [11]. However, a promising application area is neuropsychological evaluation, as computer games may have some advantages consequence of their computerized nature [12]. Testing protocols can be easily standardized, an increased accuracy in timing and response latencies can be achieved, data collection and administration is simplified, and a better randomization of the presentation of stimuli in repeated administrations is possible. In addition to that, virtual reality games have an extraordinary potential, as virtual reality tests can be developed in a way that they simulate the demands of daily life and thus improve their ecological validity. Virtual reality games may include distractions in order to simulate real-world conditions, and promote interactive participation [13]. These kind of games also support a precise representation of dynamic perceptual stimuli (visual, auditory, olfactory, ambulatory, and haptic) [14]. Finally, computer games, due to their ludic nature, are an excellent alternative to traditional pen-and-paper tests for the frequent assessment of individuals at risk [15].

We can find in the literature many experiences on the use of computer games for cognitive evaluation. Beck et al. [16] created a virtual reality assessment tool aimed at the evaluation of visuospatial orientation, which in turn is a relevant indicator of Alzheimer's disease. This game provides a 3D representation of a horizontal test tube in a wooden shelf and a toilet paper roll in a vertical metal holder. Subjects are asked to say whether a particular object is centered, shifted to the left, or shifted to the right by pressing the associated button. Authors compared, using functional magnetic resonance imaging, how brains perceived spatial properties in the virtual and the real world. They concluded that mimicking the real world in a virtual environment is not

enough for achieving ecological validity, due to the differences in brain processing in the virtual environment.

Sauzéon et al. [17] proposed a game simulating an apartment to evaluate episodic memory. Subjects would be divided into two groups, the first one would freely explore the apartment during fifty seconds, while the second one would just watch a pre-recorded video of the virtual apartment. In the test phase, subjects were requested to perform a free recall task as well as a yes/no recognition task. This game is claimed to be able to provide four memory effects relevant for establishing different cognitive impairment patterns, namely learning effect, active forgetting effect, memory strategy, and false recognitions. Note that impairments in episodic memory are frequently the first symptoms experienced by patients with Alzheimer's disease [18].

Plancher et al. [19] focused on studying episodic memory in amnestic mild cognitive impairment and Alzheimer's disease patients in comparison to healthy subjects using a virtual city that can be explored by driving a virtual car using a real steering wheel, and gas and pedals. Similarly to the previous example, they explored active and passive encoding (i.e., active subjects were requested to drive in the environment, whereas passive participants just watched a previously recorded version of the route driven by an active participant. In the test phase, subjects were requested to perform immediate recall, recognition, and delayed recall tasks. Interestingly, authors assessed the ecological validity of their game by correlating scores of participants in the virtual environment with those obtained in the Cognitive Difficulties Scale (CDS) [20].

Tenorio et al. [21] proposed a battery of games aimed at the neuropsychological evaluation of children. Among the games in the battery, Mexican House displays a complex figure that the subject has to copy providing as much detail as possible. After that, the subject had to replicate the figure, but this time without watching the original model. Authors report an excellent inter-rater reliability; and the content validity was ensured by expert assessments on the relationships between the implementation and conceptual principles.

Virtual Super Market [22] is a game in which participants have to buy a list of items in a supermarket. Participants navigate inside a virtual supermarket in order to buy the items in a shopping list, displayed at the right upper corner of the screen. After having purchased all the items, participants proceed to check-out in a cash desk. This game, initially conceived as a cognitive training tool focused on executive function, navigation, planning, and memory, was validated to be used to detect mild cognitive impairments.

In the previous examples, testing through games was administered in a controlled environment, typically in a clinical facility. However, computer games can unleash their full potential when administered in an environment where subjects will feel more confident and express a minimal rejection attitude, thus dramatically improving neuropsychological evaluation's ecological validity. This environment corresponds to the subject's home.

Cognitive assessment at home is relevant not only from a medical point of view, but also from a social perspective. The quality of life, which in turn may affect the neuropsychological status, depends upon many factors beyond health conditions. The World Health Organization defines wellness as "a state of complete physical, mental and social well-being, and not merely the

absence of disease and infirmity" [23]. Socialization is an essential requirement, in particular for elders that live alone [24]. This paper contributes to cognitive assessment at home by introducing a platform supporting, among other social and health applications, a collection of accessible through the TV. The TV set offers a much more familiar interface for many users [25][26][27] overcoming the digital divide when using an ICT-based health and care systems at home.

The rest of this paper is organized as follows: Sect. 2 introduces the methodology followed to design and deploy the proposed game collection; Sect. 3 discusses the outcomes of a pilot experience involving 62 real users in a real scenario, together with their perceptions on usability and acceptability; Sect. 4 discusses the results of the above process; and finally Sect. 5 presents the conclusions of this work.

Materials and Methods

There are four general approaches for the *gamification* of the cognitive tasks aimed at capturing the subjects' (i.e., players') cognitive performance.

1. Take an existing game and use it as a platform for creating cognitive measurable tasks by modifying game parameters. For example, the classic redemption game Whac-a-Mole [28] captures different measures such as the speed and the deviance from target. This approach takes this well-known existing game and 'hooks into' its mechanics to capture players' performance. The execution of this approach requires a good recognition of the particular cognitive abilities that are tapped by concrete tasks in video games.
2. Mimic the testing mechanics of a paper-based test trying to be challenging and fun at the same time. Differently to the first approach above, in this case the starting point is a traditional neuropsychological assessment suite, and the objective is to create a video game that has the same validity by replicating its mechanics.
3. Embed already computerized neuropsychological tests into a virtual reality environment.
4. Replicate real life situations using virtual reality environments that try to depict realistic situations like car driving in a city [29], an apartment [30], or a supermarket [84] among others.

Other approaches might be possible, such as to design a video game from scratch embedding cognitive tasks aimed at capturing performance data to enable an eventual assessment of a selection of cognitive areas. However, no practical examples were found at the time of writing this paper.

In our case, the games introduced can be classified into group 1 above. The selection, design and implementation of the game collection were performed in collaboration with the Galician Confederation of People with Disabilities (COGAMI). This entity represents all users' associations of people experiencing a broad range of disability conditions in Galicia, Spain. An occupational therapist appointed by COGAMI advised the research group on the identification and selection of a set of cognitive-related activities, which were eventually implemented as

games for our platform. Among these games, four of them were specifically targeted to neuropsychological stimulation, which will be further discussed below.

The possibility to assign scores to user interactions was also taken into account when selecting and implementing the games mentioned. Besides their utility to perform cognitive evaluation, these scores would also be visible to other users participating in the pilot. The scoring system was implemented with the advice of cognitive rehabilitation professionals to facilitate cognitive evaluation and to enhance users' motivation.

The games implemented are (cf. Fig. 1):

- *Memorion.* Each users has available a limited number of pairs of cards (i.e., every card has a duplicate card). At the start of the game, all cards are presented facedown, and users have to flip them one by one to discover all pairs of cards. In turn, each user selects two cards in sequence. If both cards are identical, one point is scored and the selection of cards is repeated again. In case the cards selected are different, cards are flipped again and the turn is passed to the next player. This game is intended to assess short memory capabilities.

Figure 1. The games used in this study are adaptations of classical games. (Photo credit: Carlos Rivas Costa)

- *Find the Intruder.* In this game, participating subjects are presented with a collection of images and they have to identify which one does not belong to the collection. During the game, images are randomized to prevent the apparition of presentation patterns and thus users from recognizing them. This game addresses the perception, decision-making, association and categorization capabilities.
- *Sequences.* Users are presented with real situations where a sequential relation occurs. This relation may be numerical, temporal, cause-effect, etc. The correct sequence of events in each situation is modified randomly and presented to the player, who has to place the events again in the correct sequence. The presentation of both individual events and sequences is randomized to prevent presentation patterns.
- *Puzzle.* Users shall complete a series of graphical puzzles. An image is divided into puzzle pieces and those pieces are shuffled. As users solve puzzles, their difficulty (i.e., number of pieces) is increased. Users are penalized in case they made a wrong selection.
- *Questions and Answers.* Users are challenged with questions about an image surrounded by additional images. Users shall provide the correct answer to the question by selecting one of the images provided.

Another relevant aspect to be analyzed is the type of device and user interfaces to support videogame interaction. The vast majority of proposals found in the literature support PC-based interaction, in most cases to a Web application, although some desktop applications are also used. Other works incorporate mobile devices, which facilitates mobility and access to videogames regardless of the location of participants. In our case, the supporting platform will be a smart TV. As discussed above, the TV set is probably the most familiar appliance, and with recent advances in information and communication technologies state of the art TV appliances have become full-fledged computing platforms.

It is also worth noting that only a few selected works used behavioral sensing—through tracking/sensing devices—to capture data that may provide information for performing data analytics. The solution utilized as the supporting platform in this project also supports a broad range of interfacing and tracking devices [28].

The validation of the usability and acceptability of the game collection was performed through a pilot test with real users in their own homes (cf. Fig. 2). Written consent was collected from all participants in accordance with the provisions of Spanish regulations [29]. No medical/health data was collected, and the only data stored and processed was that related to the participants' perception on the use of technology.

Participating users had the platform at their disposal during a period ranging from 7 to 15 days. Participants had to be at least 65 years old (i.e., retirement age in Spain at the time of the pilot), and have a broadband Internet connection at home. Eventually, a total of 62 subjects were selected among volunteers affiliated to the Third Age Lecture Rooms of Galicia – ATEGAL association. Gender distribution was 50% - 50%, and participants were scattered around the region of Galicia, Spain. This region is characterized by being a mostly rural area, and by an aging population. To guarantee common deployment conditions (i.e., common evaluation settings), the platform was implemented in a home theatre personal computer (HTPC) connected

to the users' television sets. This solution enabled us to convert any existing TV set, regardless of its age or underlying technology, into a standardized smart TV.

Figure 2. Pilot testing was performed at participating subjects' premises. (Photo credit: Carlos Rivas Costa)

The pilot test was organized into two phases involving 42 and 20 subjects respectively. In each phase, users were divided into groups of at most seven people living in the same area. Then, the platform was installed simultaneously in those seven premises. Users were asked to interact with the platform at will. All settings included exactly the same games. To collect usage data and users' perceptions, two questionnaires were distributed, one to be completed before the pilot and a second one to be delivered right after it.

Results

Participants were asked about the perceived usefulness of the games implemented. 57.1% perceived them as very useful, and 33.3% perceived them as useful (cf. Fig 3). In other words, more than 90% of participants declared that the games were not just an entertainment option, but also a means to exercise their memories and their reasoning capabilities.

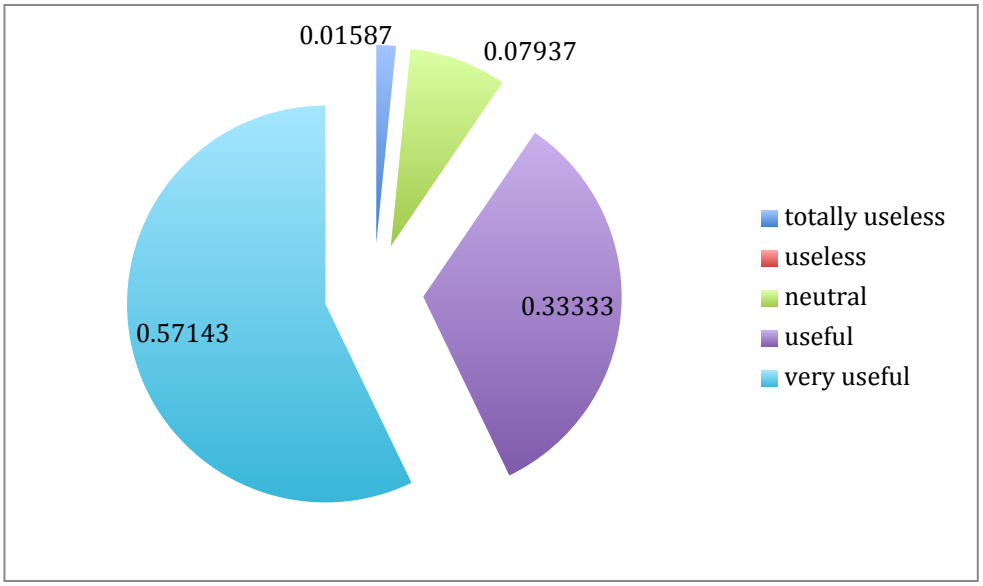

Figure 3. Perceived utility of cognitive games

They were also inquired about the perceived usability. More specifically, they were asked whether it was easy for them to play with the games on TV. In this case, results were very similar to the previous case, and a strong correlation exists between subjects declaring that the games were useful / very useful, and users declaring that it was easy or very easy to play with them (cf. Fig. 4).

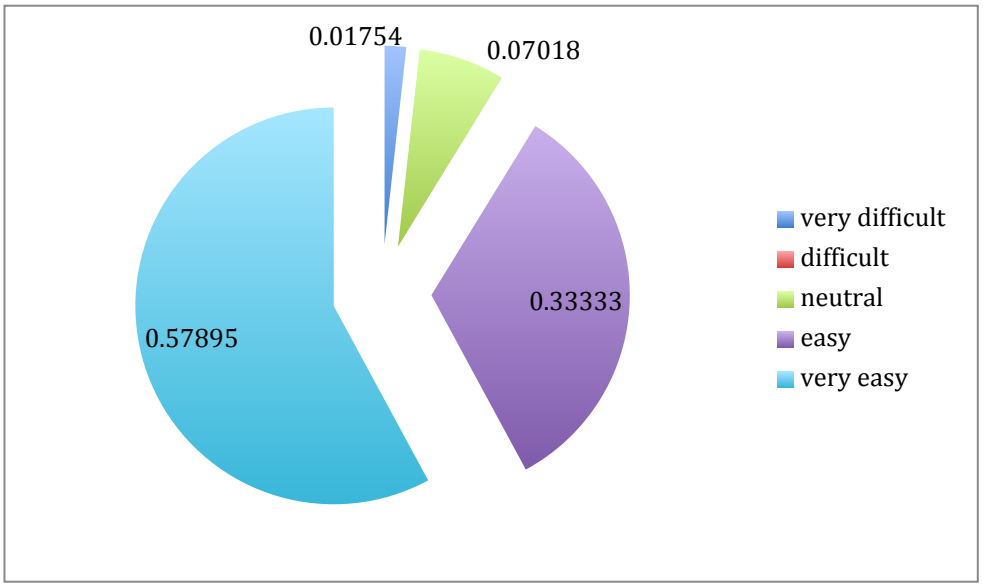

Figure 4. Perceived usability of cognitive games

Conclusion

The study confirmed that senior adults perceive that they can check their cognitive status by themselves, at least in an informal way, by means of playing particular games designed to challenge their memory or their reasoning capabilities. Besides, the participants in the pilot

discussed above perceived the TV set as a convenient device to interact with those games. As a consequence of the perceived usability and acceptance of games as a means of cognitive evaluation, we can confirm that there is at least initial evidence about the convenience of using serious games to assess the cognitive status of senior adults at home using the TV set as the interaction device.

Nevertheless, in spite of this promising initial evidence, more research is needed in order to implement serious games in a way that they are widely accepted by the medical community as a valid, reliable way to perform cognitive evaluation at home.

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