Acceptance of Cognitive Games through Smart TV Applications in Patients with Parkinson's Disease

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Abstract **Different types of dementia associated to later stages of Parkinson's or Alzheimer's diseases may include memory loss and difficulties with thinking, problem-solving or language. People affected by such diseases may also experience changes in their mood, expressiveness or behaviour which can provoke a communication impact in their lives and problems for socializing. Preventive policies, such as a balanced diet, daily exercise, frequent intellectual activity and interaction with others are protective factors that could help to reduce (or at least to delay) the effect of this cognitive impairment. Cognitive electronic games are an effective methodology to develop cognitive training and to stimulate the brain activity in this kind of patients. The user's interaction information allows analyzing the cognitive training and drawing conclusions about their evolution in controlled environments supervised by a professional. Preliminary tests revealed that users are familiarized with the use of televisions facing other devices such as tablets or smartphones. For that purpose, a Smart TV application containing different kinds of cognitive games, such as Bingo, Trivial or Memory was developed, taking benefits of the Connected TV environment. The Smart TV device for cognitive games received a good acceptance while tested among caregivers, patients and professionals, as demonstrated after testing the cognitive games individually and also collectively in daily care centers. Those tests revealed that the use of this device was a good chance to improve socialization with collaborative gaming, as this activity obliged them to communicate with other people and interact with their surrounding environment.**

CCS Concepts: • **Human-centered computing** ~ Empirical studies in HCI • **Social and professional topics** ~ Seniors • **Applied computing** ~ Health care information systems

Keywords—Cognitive games, Parkinson, Alzheimer, dementia, preventive intervention, Smart TV Application.

I. INTRODUCTION

Parkinson's disease (PD) is a disorder characterized by degeneration of dopamine-producing cells in the substantia nigra (SN) and to a much lesser degree in the ventral tegmental area (VTA). This deficiency produces the cardinal motor symptoms of tremor, rigidity, and bradykinesia [1]. PD patients also present several non-motor symptomns, such as cognitive decline, often predicing motor signs by many years with a negative impact on quality of life, increase care giver burden, an annual economic costs (estimated at ~ 14 billion in Europe) [2].

Unfortunately, the origin of PD is still unknown. Age remains the most important cause documented so far, although complex interactions between genetic and environmental factors, including pesticides and other toxics, are probably involved [3], [4]. Because the incidence of PD increases sharply with age and because the world's population is aging, the number of individuals affected is poised for exponential growth. The Global Burden of Disease Study estimates that 6.2 million individuals currently have PD and projections are that the number of people with PD will double to 14.2 million in 2040 [5], [6].

The management of Parkinson's disease has traditionally centred on drug treatment, but even with optimal medical management, patients experience a deterioration of mobility and cognitive sympthoms that increment the risk of social isolation reaching implications for patients and their families [7].

Cognitive decline in PD includes deterioration in diverse functions and skills. To date, there is considerable evidence of damage in executive functions such as working memory, attention, reasoning, and planning even in early nondemented PD patients [8]. Perceptual visuospatial and verbal processes have been shown consistently to be impaired in PD [9] and decline in memory have also been documented [10]. Cognitive deficits are very prevalent in PD patients. At the time of PD diagnosis, approximately 30-50% of patients already exhibit symptoms consistent with mild cognitive impairment (MCI) or dementia [11] and from 60 to 80% of cases develop into full dementia within 10 years [12]. Consequently, developing alternative or adjuntive therapies such as cognitive stimulation, cognitive training, and cognitive rehabilitation are imperative.

Cognitive games are an easy and economic methodology for stimulating particular cognitive functions such as memory, visual attention, object recognition, short-term memory or problem-solving. Additionally, in the case of electronic games, the interaction and response of the patient to cognitive games can be registered for offering valuable information that can

redound in feedback about the disease evolution, when developed under the supervision of a professional. For this purpose, the DIT (Data Interaction Tracking) database was created to store each interaction by the user with timestamp information, results and other data to develop statistical analysis.

A large percentage of patients affected with PD are not accustomed to electronic games and internet environments, especially in cases of elderly patients. For that reason, it is necessary to focus on devices which they are familiarized with, such as televisions, with easy interaction like through remote control, and screens adapted to low vision. An architecture based on Smart TV in domestic environments is demonstrated to be an easy-to-use technology to provide social and health care [13]. Thus, electronic games in this environment are suitable for any kind of user with PD and games applied as cognitive tests are cost effective tools to facilitate daily cognitive assessment through personalized, motivating and reliable tests [14]. Tests with conventional games, such as memory retention games or Bingo [15], [16], demonstrated the value of this kind of tools for cognitive training and stimulation, but also for socialization among patients and caregivers, family members, or any other person while playing.

Regarding caregivers, they play a key role in preserving an acceptable quality of life and some independence for PD patients, and their presence has been reported to decrease morbidity and mortality rates in PD [17]. This role is generally filled by a relative, partner, or close friend. As the disease follows its natural course, caring for the patient frequently becomes the caregiver's main activity [18]. So it is important to seek their active collaboration and to gather and analyze their impressions on the Smart TV device in order to better achieve our intervention goals.

Similar studies were taken into account, such as the observation of cognitive training applied to patients with schizophrenia [19] and the service of cognitive stimulation applied to Parkinson's disease patients developed by García-Vázquez et al [20].

II. Material and Methods

Though traditionally the electronic games were designed for entertainment and socializing, when played in groups, their use by psychologists for research, understanding of cognitive capacity and preventive intervention has increased. But any device that pretends to serve for those uses mentioned above needs be accepted in a first term by its users. So, in the first phase of this research we have included the following objectives:

- To know the acceptance level of the Smart TV device for users affected by PD.
- To check professional and caregivers' opinion on the Smart TV device to be used by PD patients.

Data have been collected through different research techniques: individual testing, collective testing and focus groups with three different types of users: professionals, caregivers and patients. First, deep individual testing was performed to examine different Smart TV components with one patient at a time though a define task list agreed between research partners. This way user' spontaneous suggestions about different functionalities in terms of design, usability and requirements were gathered. Secondly focus groups were carried out with health professionals. Those were specially designed to better understand patient's preferences collecting further qualitative feedback from users groups in terms of user's needs and opinion about the developed components of Smart TV. The researcher presented specific features of the system to participants and collected feedback with the help of focused questions and moderation, ensuring the fluidity of the conversation.

The methodology for focus group development in applied social research is mandatory in order to maximize potential of this qualitative data collection method [21]. The design of the experiment must be adapted to the type of evidence to be obtained, in this case the acceptance, needs and requirements of the Smart TV application were developed for patients with Parkinson, Alzheimer and other kinds of dementia that affects to cognitive performance taking into account the end user needs. The researchers were able to observe and interact with the application before the users were asked a list of questions about usability, interface design and usage environments. The role of the moderator was completely neutral, not to distort the results obtained through free responses, but explained the purpose of the tests, made a demonstration of the object of study and answered all the arisen questions during the session.

Collective testing was also performed with caregivers. During those sessions users were exposed to a similar walkthrough as in deep testing, giving them the chance to assess on the general concept and concrete developments of the Smart TV though an assessment questionnaire.

Those techniques allowed reaching the following number of users:

- Health professionals: 11 users participated in a single group session to give their opinion about the Smart TV application. Health professionals, mostly physiotherapists were involved in the learning of the tools developed offering their feedback on the use of the device for PD patients through open questions
- Caregivers: 9 caregivers in two group sessions of 45 minutes each (4 in the first and 5 in the second) filled also a questionnaire to give their impressions about the Smart TV application for the cognitive games.
- Patients: 16 patients in several individual or group sessions of maximum 45 minutes tested the cognitive games to offer data that it was stored in the DIT database and afterwards processed statistically.

Results of the testing revealed good acceptance by these three groups in the use and performance of cognitive games. Regarding the Smart TV App, 75% of caregivers would recommend the use of the application with their relatives, but especially in environments where someone else is supporting them, because most of them use regularly television, tablet and

mobile at home, and this could improve their interaction with internet and this type of devices.

Fig. 1 corresponds to the feedback provided by 10 Alzheimer's and 10 Parkinson's patients who accepted to answer the question *How would you rate the Smart TV app?* The results of this analysis show that 7 Parkinson's patients out of 10 provided a positive feedback to the Smart TV, while most of the Alzheimer's patients rated this component as "average". Parkinson's patients' opinion about it is more positive than Alzheimer's patient's one.

Those results can be explained through the different patients' perception of the use of the ICTs (Information and Communications Technologies) and the feeling that they may learn how to use the tested components. According to the results of the testing and as explained by the health professionals, for Parkinson's patients it is possible to learn and to make progresses in the use of a device, while for Alzheimer's patients this would be really challenging, especially for advanced stages. The possibility to learn how to use a device may have an important impact on the acceptance of the ICT tools, because if the users feel that they can learn how to use a device they would be reassured and more keen to give a positive opinion about it; while the users who perceive the technology as an obstacle and an added difficulty would have a negative feeling about the device since they do not know how to use it and see it as an new obstacle rather than as a supporter in their life.

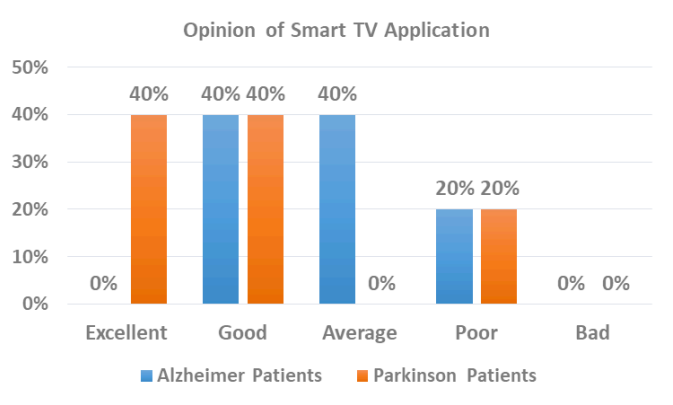

Fig. 1. Scheme of cognitive games application functioning

On the other hand, Fig. 2 shows the opinions about the ease of use of the different components presented developed in the project's environment. The Smart TV was rated the easiest component to be used by the patients and the caregivers (18 users' positive feedback out of 33) during the deep tests, as illustrated in the figure here below. Only some minor corrections are still needed, such as the increase of the icons and texts size.

According to the results of the Satisfaction questionnaire used during the deep testing, 18 patients and caregivers out of 33 who accepted to answer the question, said that the Smart TV app is the easiest component to use because they are accustomed to use the TV set and also because the screen is big and guarantees a better vision of the texts/icons

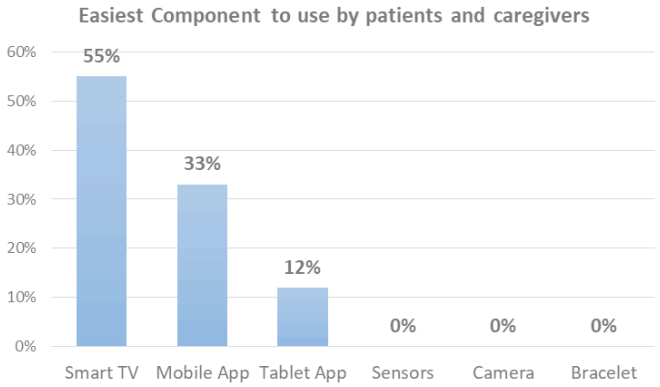

Fig. 2. Subjective Ease of use of devices by patients and caregivers

As a confirmation of the good level of acceptance of the Smart TV, the Fig.3 shows results during the deep tests.

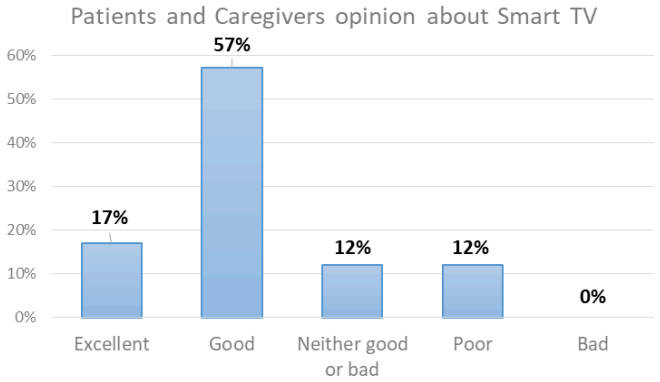

Fig. 3. Subjective quality of the Smart TV application by patients and caregivers

III. Smart TV Application And Cognitive Games Description

In this section, we describe the main aspects of the Smart TV application and its main functionalities associated to electronic cognitive games. The system has been developed based on Android TV following the scheme shown in Fig. 4. This technology has been selected due to its high popularity and compatibility with Operative Systems. More specifically, Android TV is endowed with friendly graphical interfaces and presentation functionalities that increase accessibility and therefore usability by target users. In order to implement these services, the system employs an Android TV Box with minimum requirements: Android 5.0, HDMI, Wireless remote control and Ethernet or Wi-Fi connectivity.

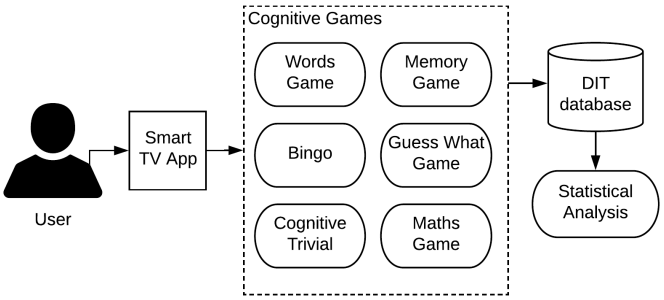

Fig. 4. Scheme of cognitive games application functioning

A collection of games has been developed for stimulating different cognitive user's capacities: *Memory game*, *Bingo*, *Guess What*, *Maths*, *Trivial* and *Words*. The interaction with the application generates information that is stored in the DIT (Data Interaction Tracking) database for statistical analysis to draw conclusions about the patient's behaviour and gaming methodology. This information is also useful for generating recommendations about healthy habits and other games. The application was developed in four languages (Spanish, French, Hungarian and English) according to the requirements of the iterative testing's and pilots of the project.

The *Memory game* requires that the person distinguish and match colors and shapes, so it is beneficial at a cognitive level, especially for short-term memory training. The goal of the game is finding pairs of cards with the same object hidden from a grid with a determined number of cards. Players can identify anything from animals to items of food, to body parts, although in the first example version cartoon characters are used as the items to find, because they have different colors and shapes, and this is visually stimulating. The game contains three different levels based on the number of cards for increasing progressively the difficulty. Additionally, there was a prototype version including the faces of relatives, oriented to patients with Alzheimer's disease.

The *Guess What* game stimulates memory and capacity of recognition of an object. Visual perception of the image specifically provides mental stimulation that is highly therapeutic. The goal of this game is to guess what is hidden in the image before the time is finished. At first sight the image is completely blurred and as time goes on the distortion of the image decreases progressively, so players have 40 seconds of time to guess it among four different choices. There is also a cognitive version that does not employ distorted images for patients with severe visual impairment, to challenge the user to identify objects.

The goal of the *Words* (*Hangman*) *game* is to arrange the letters and fill in the blanks to find the scrambled word. This game evaluates short-term memory, concentration, word retrieval, and word recognition for vocabulary and lexicon evaluation. A virtual keyboard was implemented on screen for selecting each letter with buttons with a high contrast. Additionally, a series of balloons explode when the letter is not included in the word for motivational purposes. Voice synthesis tools help the user in the process facilitating the accessibility to interaction with the game.

Trivial is a game in which winning is determined by a player's ability to answer general knowledge and popular culture questions. Each question presents four different choices, and only one is the correct answer. The game has different categories, such as object recognition. This game requires several cognitive functions, such as attention, memory and planning, but it also requires decision-making upon encountering new stimuli. The version with *Maths* questions stimulates the patient's abilities for calculation and numerical understanding.

Finally, the *Bingo* game is conceived as external supports that enhance visual attention and objects recognition for improving cognitive task performance through self-generated strategies. Visual perceptual functioning is reduced to varying degrees in normal aging and in individuals with the age-related neurodegenerative disorders of Alzheimer's disease (AD) and Parkinson's disease (PD). The game is also useful for enhancing socialization when played in daily care centres to integrate patients that demand the same necessities. Bingo game with numbers is useful for patients with this type of disorders, but for enhancing visual attention, the numbers were substituted by colourful objects, in this case fruits and food to motivate the users and, for cognitive reasons, to improve their ability to recognize objects by colours and shapes.

IV. Results and Discussion

Among the most important aspects that demonstrates the acceptance by caregivers, professionals and patients, the following conclusions are drawn:

- Positive acceptance of the application by patients and caregivers as they consider it is easy to access to it though their TV set and it is an enjoyable activity to perform.
- Good acceptance of the games as "it encourages the interaction of the patients' with persons around them" and it can be useful to train cognitive skills and to entertain. "The importance to prompt patients to keep themselves cognitive active realizing this kind of joyful games".
- According to professionals' and caregivers' feedback, the games on Smart TV could encourage the interaction of the patients' with their caregiver, their relatives or Friends. The possibility of an intergenerational interaction has also been proposed by participants during testing, who said patients might play the games with their grandchildren, for example.
- Parkinson's patients were able to understand the app and learn how to use it improving their testing performances with the Smart TV along practice.
- Patients with low ICT skills had more difficulties to use the Smart TV, as expected.

- Movement problems linked to the disease were considered and recommendations were produced in order to facilitate the patient's use of the technology. One of the most important bits of feedback it was regarding the use of the remote control of the Smart TV application, because handling could be hard for a Parkinson's patient. Therefore the suggested solution which came out during the testing was either to use the remote control with bigger buttons or to support the patient in the use of it.
- During early testing it was reported that the level of the games need to be adapted to patients' skills and different difficulty levels were implemented. Afterwards, during first iterative testing phase it was reported that navigation resulted complicated because of colours and colours were modified to make navigation easier.

An example of the results obtained through the Bingo game are collected in Fig. 5. Two consecutive Bingo games were played by the same group of three PD patients. The analysis of the game is based on calculating the times needed for finding and recognising an object by the group of PD patients, as a consequence of the visual attention and recognition skills of the patient. The time in seconds to find each object in the first game is higher, as seen on the higher slope of the "Game 1" (blue) line. On the other side, "Game 2" (orange) line reveals that the time to play the game was shorter and, as a consequence the evolution of the game was faster. This fact demonstrates that an improvement in learning process of the patient exists.

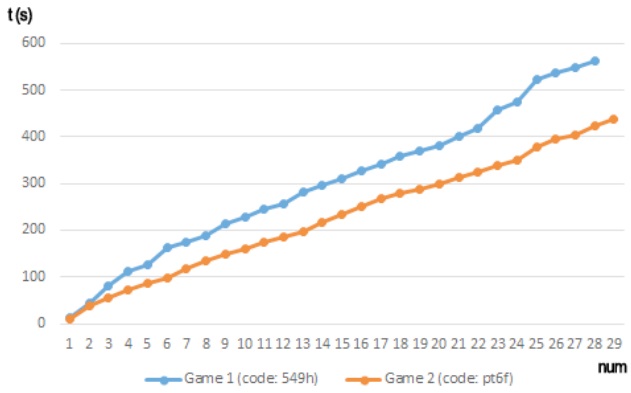

Fig. 5. Comparison between the time flow (in seconds) of two consecutive Bingo games, where "num" is the number of the extracted object from 1 to 30.

Fig. 6. Comparison between avarage time to take a letter in "Hangman" game, in comparison with the result of the letter chosen

Fig. 6 contains an example of "Hangman" game, comparing the times of extraction of letters. This measurement helps to understand the behaviour of the user when succeeding in a simple task or not and the reaction to this concrete behaviour. The times when selecting a letter in the game and the consequence of obtaining a score (or not) have influence in the motivation and development of the game.

The facts analysed from these examples could help the professionals to understand the behaviour of the patients and their capacity to learn from the processes.

V. Conclusions

The different types of research and preliminary tests with PD patients, professionals and caregivers demonstrated that the Smart TV application and the cognitive games implemented for this device are a useful tool for entertainment, socialization and cognitive stimulation. The application received a good acceptance among the different types of users involved in the sessions. One of the reasons is because they considered the device of easy interactivity through remote control, especially when it fits in their hands, because they can handle it even overcoming the mobility problems. This fact was demonstrated for collective and individual sessions after testing the cognitive games with these three different categories.

Tests of the Smart TV application in daily care centers also revealed the chance to improve socialization with collaborative gaming. Test developed with users in groups of two or three patients performing this activity obliged them to communicate with other people and interact with their surrounding environment, and helps to overcome the social isolation that provokes PD.

Finally, the obtained results that demonstrate the acceptance of the Smart TV application suppose a starting point to analyze valuable data for the patients in testing the validity of cognitive games as preventive intervention for the cognitive decline.

Annex I. Questionnaires

1. Walkthrough questions (for individual testing):
   - Was the participant able to complete the task?

- Time to complete the task
- Did the participant asked for help to complete the task?
- If so, how many times did the participant ask for help?

ACKNOWLEDGMENT

This work has been partially supported by the EU project ICT4LIFE [22]. This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement no. 690090. The authors would like to acknowledge the professionals, caregivers and patients who disinterestedly participated in the different tests.

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