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Game Based Monitoring and Cognitive Therapy for Elderly

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Abstract. As the proportion of older adults grows, the number of special care provisions to help individuals with declining cognitive abilities needs to also increase. Information Communication Technology (ICT) is beginning to play an increasing role in facilitating the work of specialists to support and monitor individuals with cognitive impairment within their everyday environments. In addition, advances in artificial intelligence and the development of new algorithmic approaches can be used to approximate the computational processes of human behaviour in different circumstances. In this paper, we report on the development of a software system using game based therapies for older adults in Mexico suffering from cognitive impairment, where this system has been deployed in a unique day therapy centre. We further propose an evaluation module based on using AI approaches and affective sensing to monitor and detect significant changes in performance cognation that might indicate a possible cognitive decline.

Keywords. Cognitive Impairment, Alzheimer, Computer Assisted Therapy.

Introduction

The world's elderly population is growing significantly and coupled with this, the number of elderly people with cognitive impairment too (see Fig. 1). According to data from the Alzheimer's Association, in 2010 the world's population of older adults over 60 was estimated at 758.54 million people, of which 35.56 million (4.7%) had dementia. However, a significant increase is expected in the coming decades, where this number will reach 65.69 million by 2030 up to 115.38 millions by 2050 [2]. In the case of Mexico, the National Institute of Neurology and Neurosurgery (INNN) reported in 2010 more than 350,000 people affected by Alzheimer's disease and that annually 2,030 patients died from it [3].

Furthermore, according to INEGI (Mexican Institute of Statistics, Geography and Informatics), in the specific case of Mexico in 2000 the number of people over the age of 65 reached a total of 4,750,311. Population projections rank Mexico among 10 countries that is set to rapidly increase number of elderly people over the next 30 years, which is projected to reach more than 15 million by 2030 [1].

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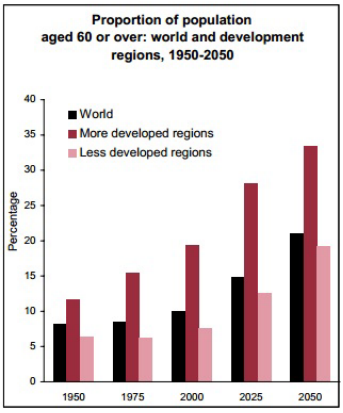

Figure 1. Proportion of population aged 60 or over 1950-2050 [17].

Due to the growing rate of the ageing population, government funds may be insufficient to cover all their needs. Additionally, it is important to notice that not all the people will be able to qualify for a pension (and the probability of finding a part-time job decreases dramatically with age). For these reasons the Institute of Memory (supported by The Alzheimer Institute of Leon Guanajuato, Mexico) was established in 2005 due to the lack of specialized institutions in the treatment for patients with cognitive impairment, with the aim of creating an interactive program of cognitive stimulation to enable both the intervention and prevention of cognitive decline in the elderly.

The Institute offers various services such as a unique Mental Spa (with different activities such as workshops for elderly, and cognitive stimulation programmes), workshops for carers, senior nutrition and diet tips, psychotherapy and support groups, and a wide range of group activities such as cine club, ballroom dance, swimming lessons, and tai-chi among others.

Observing a patient's activities can be used to monitor and assess cognitive impairment and decline. For example, early stages of cognitive impairment may cause forgetting certain steps in familiar tasks or difficulty in performing new and complex tasks. As such in February 2011 the Alzheimer Foundation Leon (FAL) proposed a joint venture with Leon Institute of Technology (ITL) to develop a software system called *Mente Activa* that allows the use of therapies through cognitive stimulation exercises to benefit FAL patients who suffered from cognitive impairment or dementia.

An initial version of this system has now been deployed and is being assessed by patients at the Memory Institute. An additional need to monitor patient's cognition both during the therapy sessions and remotely from home has been identified as useful for diagnosing cognitive impairment and monitoring progression of cognitive decline. We therefore further propose an extension to the existing system though the incorporation

of an intelligent evaluation module that would analyse patient performance data acquired from the *Mente Activa* system. We also consider the use of affective sensing technologies that could be used to unobtrusively monitor certain physiological parameters for monitoring emotive drive aspects of cognition such as engagement and arousal or frustration while interacting the simulation exercises. These might give us a more accurate picture of the patient's cognitive abilities, progressive decline of these abilities, to facilitate more targeted support.

This paper describes the development and deployment of the software system and current work on the integration of an intelligent evaluation module to facilitate proper monitoring of patients progressive conditions at both the treatment centre and at home. The rest of the paper is organised as follows. Section I introduces the challenge faced and the important role of the technology. Section II is about some popular game-based proposals for cognitive treatment and its main features including disadvantages for Latin-American context. Section III points out our approach in order to clarify its structure and how it is organized. Section IV is related to an evaluation module that is being developed in order to detect important interaction changes on the user's performance with the software and its activities. Section V defines one of the main targets of the evaluation module. In section VI the conclusions and future work of this research is presented.

1. COGNITIVE IMPAIRMENT

1.1. Dementia

Dementia is a term used to describe various different brain disorders that have in common loss of brain function which is usually progressive and eventually severe. There are over 100 different types of dementia. The most common are Alzheimer's disease and vascular dementia. People with dementia have particular problems with their short-term memory forgetting consistently recent things, losing the sense of time and place [4].

1.2. Alzheimer

Alzheimer's disease is a progressive and fatal disease of the brain. It is a degenerative disease of the brain that leads to a condition called dementia. Dementia is a general term used to describe the loss of memory and mental abilities severe enough to affect daily life [5].

1.3. Technology applied in cognitive impairment

While human caregiving cannot and will not be replaced, assistive technologies that can supplement human caregiving have the potential to improve the quality of life for both older adults and their caregivers. In particular, assistive technologies now being developed may enable older adults to "age in place," and remain living in their homes

for longer periods of time. A number of systems have been developed (for example Activity-Guidance Systems [22] or game based assisted physical therapy [23]) for helping people compensate the physical and sensory deficits that may accompany aging, especially older adults who are grappling with cognitive decline.

The Assistive Technology applied on interactive games can assist older people with cognitive impairment to measure cognitive performance by monitoring a person, and also they can be benefit: (1) by providing assurance that the elder is safe and is performing necessary daily activities, and, if not, alerting a caregiver; (2) by helping the elder compensate for her impairment, assisting in the performance of daily activities; and (3) by assessing the elder's cognitive status. There are some projects that support these facts, and they have shown that older adults enjoyed these activities because it incorporates aspects of cognition such as short-term memory and strategic planning that are directly relevant to the performance of activities of daily living [6].

2. RELATED WORK

There are several cases of technology-based tools focused on helping and supporting cognitive therapy; however not all of them are currently available on the market.

2.1. Smart Brain

Smartbrain is software developed in Spain, with an interactive multimedia approach that develops cognitive abilities (memory, concentration, language, recognition, calculation, etc.) of people with mental deterioration caused by aging, brain injury, mild and moderate neurodegenerative diseases (Alzheimer, Parkinson, etc.) or dementias [7]. With this software, specialists can define custom treatment plans for their patients and they can perform the activities indicated from home, without travelling to a specialized centre.

This system allows patients to develop cognitive skills. However, it's application in the case of Mexico has the following disadvantages: the software handles an European context, which is meaningless to Mexico or Latin American population. Due to the previous, in some cases the concepts and activities could have different meanings. Additionally the system does not consider historical or cultural facts rooted in Mexican or Latin-American context. Finally, Spanish accent is different from Mexican accent.

2.2. DIANA

DIANA (DIAgnóstico Neuropsicológico Automatizado by its Spanish acronym) is a Cuban neuropsychological evaluation software, fully automated and developed by the Centre for Neuroscience of Cuba. This software enables management of customized versions of 27 traditional neuropsychological tests that evaluate major cognitive domains and includes a task to explore the state of the affective functions. Among the best known are the Continuous Performance Task, Path with Milestones, Digits and

Symbols Pairing, Pattern Matching, Estimation of speed, Stroop Test, Wisconsin Card Draw Categories Training test [8].

Despite the fact this software considers a Latin American context, one of the main disadvantages is that this software has not been updated (it was originally launched to the market in 1996), therefore it could be consider obsolete, and unfortunately is not on the market anymore.

2.3. Lumosity

Lumosity is a brain training program based brain games and exercises developed by an american company. Based on the concept of "neuroplasticity" (the brain's ability to learn and adapt to receiving an appropriate stimulus) games and exercises are designed to train and improve: memory, attention, processing speed and cognitive control [10] However, this software has two main disadvantages: the system was designed to help people in general to improve their memory and ability to learn; it is not fully adapted to patients with some cognitive impairment. Additionally, the personal license to use the online system requires monthly payments which does not apply to groups of persons or institutions.

3. PROPOSED APPROACH

Although there are a number of systems on the market (Smartbrain & DIANA) specifically designed for supporting specialists and patients in the treatment of cognitive impairment, in the case of Mexico in particular, these tools are not fully adaptable to language specific customs and usages (the use of European context for the exercises and activities, the lack of historical and cultural facts related to Mexico, and Spanish accent). This makes such tools almost impossible to use as a support system for patients suffering from cognitive decline. Most patients are also unfamiliar with the use of computers, mouse, etc. Due to the previous, in 2011 Leon Institute of Technology in collaboration with the Alzheimer Institute of León began the developing of cognitive stimulation software called Mente Activa.

3.1 Mente Activa

Mente Activa is a software for the prevention, detection, evaluation and monitoring of older adults with cognitive impairment and dementia. The software allows cognitive stimulation through the use of interactive games specially designed by psychologists, running on computers with touch screen and multimedia items.

The design, planning and development of Mente Activa required the collaboration of a multidisciplinary team, initially formed by five psychologists, one neuropsychologist, one neurologist, one graphic designer and two experts on education.

The computer programming and implementation was made by a team of programmers from Leon Institute of Technology. These students, from different semesters and chosen due to their programming skills and interest on participating in a real development problem, were coordinated by a group of professors and researchers from the ITL.

3.2 Software Features

a) Design

The system was designed to be as user friendly and intuitive as possible to the user, taking into account that the common denominator of the people who will use it are not familiar with the use of these technologies. The software therefore makes a wide use of multimedia elements such as images and audio (see Fig. 2).

Figure 2. Screenshot of the administrator module.

b) Developed Modules

The following modules have been implemented as part of the system:

1. User Module: In this module all the information related to every user (patient) is managed: personal data, additional information, status, medication, medical history, substance abuse, diagnostic.
2. Module groups: this module manages the groups created by the administrator.
3. Preview module: this module displays different exercises according to several criteria: cognitive function, activity type, and level.
4. Template Module: in this module a template of a set of exercises can be created in order to define a personalised stimulation plan.
5. Play module: is the module which actually runs and displays the exercises defined in the template module.

It is noteworthy that the exercises are divided primarily by type of cognitive stimulation [12, 13] based on seven key areas: language, gnosis, executive functions, calculus, attention, memory and orientation (see Fig. 3).

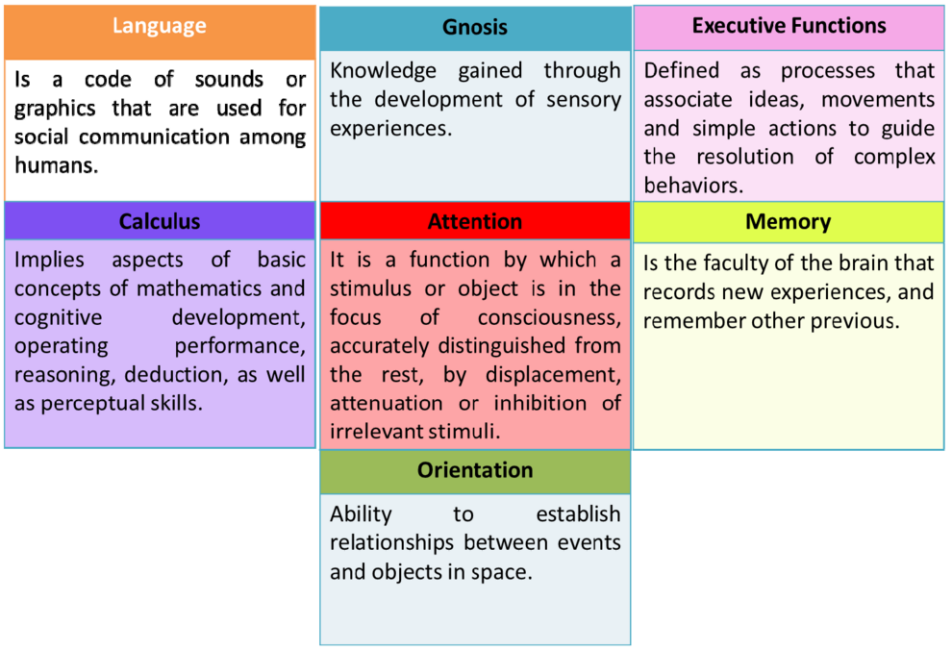

Figure 3. Cognitive stimulation is based on seven areas: language, gnosis, executive functions, calculus, attention, memory and orientation.

Associated to each exercise, an alphanumeric nomenclature was created. This code was formed in the following order: the corresponding mental function (e.g. G for Gnosis), the number of exercise, the level of difficulty (on a scale of 1 to 10) and the number of the exercise.

3.3 System deployment

The software Mente Activa makes use of MySQL as management database system, and Java as programming language. It also included the Java Runtime Environment & Java Virtual Machine [21]. The system was specially designed for interacting with the user through a touchscreen, being that most of the users on the third age are not really acquainted about the usage of computers, so all the activities are focused on being intuitive and easy to understand. In Figure 4 we can see some examples of activities (according to Fig 3. distribution). In Fig. 5 a user interacting with the touchscreen is shown.

4. EVALUATION MODULE

Facilities at the Memory Institute, include two modules, one of these, is dedicated to the day centre, where patients receive comprehensive treatment, including cognitive stimulation, among others. In this sense, the incorporation of an intelligent module is a

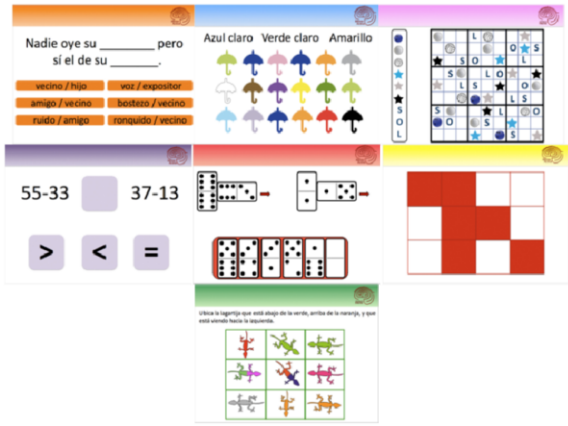

Figure 4. Examples of some activities, according to Fig. 3.

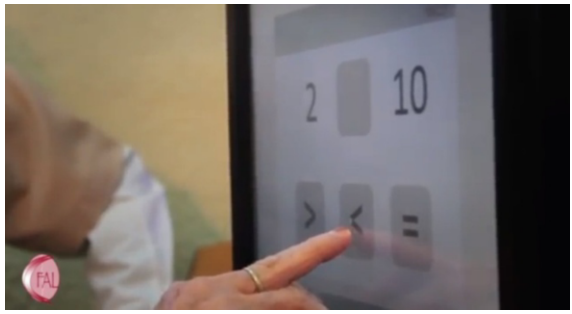

Figure 5. Example of a user interacting with the software.

pressing need, because of the amount of patients being cared for and the requirement for proper monitoring of patients within both the treatment centre. There is also a need to provide a means of allowing remote monitoring of patient at home due to the fact the in many cases these patients live alone with periodic contact with relatives and hence are more vulnerable to their condition worsening as well as other health related problems such as developing depression and injury or hospitalization caused from accidental falls.

An increasing number of devices rely on Artificial Intelligence (AI) and other advanced computer-based technologies. A range of artificial intelligence techniques has been used in the design of advanced assistive technologies. Examples include text-to-speech systems for people with low vision; a digital programmable hearing aid that in-corporate a rule-based AI system to make real-time decisions among alternative signal-processing techniques based on current conditions; and jewellery like device that allows people with limited mobility to control household appliances using simple hand gestures. In addition, significant research has been done to design obstacle-avoiding wheelchairs, among several other applications [6].

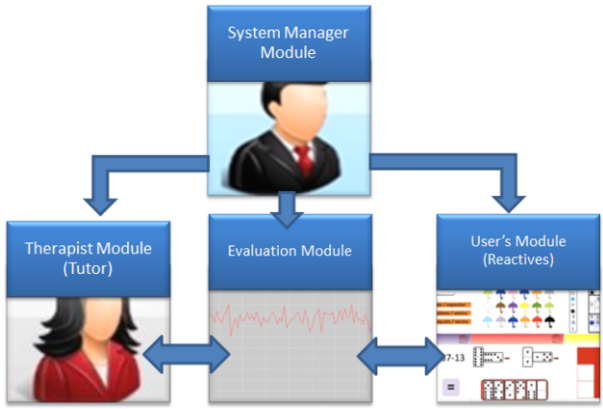

Figure 6. Propose of Software Restructure.

As we mentioned previously, our system can be used to detect changes on the performance of the user, and this could help in the early detection of dementia and Alzheimer. At the moment we are working on the design and implementation of an intelligent module that analyses the performance of a user, based on the execution of the game and the emotional state of the user, allowing automatic feedback to the user. This could be visualized in a better way in Fig. 6, where we can see the hierarchical dependencies of the modules.

For this problem, it seems to be necessary a support tool, with the aim of provide the characteristic therapy data to the specialist and suggest a series of exercises based on performance. Given that therapeutic monitoring can be insufficient due to shortage of specialists, the quality of the therapy can decrease.

Due to the necessity of recognizing the emotional state of the user through the interaction with the different activities, we will gather and analyse the electro dermal activity using a skin conductance meter device, as it has been found that this signals are correlated with the individual's emotional state. Using this technique, the system can detect alterations associated with emotion, cognition, and attention [24] that could be very useful in the selection of activities specially designed for the user's needs.

The development of the proposed performance evaluation module will involve the analysis and evaluation of a number of different AI algorithms that allow us to monitor the user's characteristics and performance on the simulation exercises. At current phase, we are analysing these following algorithms: Artificial Neural Networks, given that there is evidence demonstrating that it is possible for a computer system to recognize patterns of human behaviour through the interaction with a smart environment using neural networks as classifiers [15]. Also we are considering Fuzzy Logic, because the analysis of the behaviour and performance of humans involves uncertainty, such as uncertainty that two people can have different expressions and perceptions of the same stimulus. One example of an implementation using this technique is reported on [14]. A third option is Probabilistic reasoning, as it may

represent a way of analyzing events of user interaction with the software through probabilistic approach relativity. For example, using Hidden Markov Model [16].

5. AFFECTIVE SENSING

Affective computing (AC) is concerned with emotional interactions performed with and through computers. It is defined as "computing that relates to, arises from, or deliberately influences emotions" as initially coined by Professor R. Picard (MIT Media Lab)[18]. AC seeks to facilitate research through the recognition, modelling of human affective states. Practical applications of AC based systems seek to achieve a positive impact on human everyday lives by monitoring, communicating or affecting the emotive states of people. Affective sensing can be considered as being physiological sensors that can be used as part of an intelligent emotional recognition system to elicit an individual's physiological responses and interpret their emotional states in response to stimuli or task specific interaction physiological sensors for measuring heart rate, temperature and electro dermal activity / Galvanic Skin Response (GSR) have been used to recognize and measure states of stress, arousal and engagement in previous research [19].

Most of the systems currently on the market comprise of obtrusive sensing equipment which are only suitable for laboratory use. There has however been some effort to produce unobtrusive physiological sensor platforms with small form factors which are designed to be used in real world setting for unobtrusive monitoring [20]. Our belief is that these sensors could be integrated as part of the proposed evaluation module. This would enable task specific emotive responses to be captured from patients in context of monitoring their performance on Mente Activa simulation exercises. This could help to determine changing levels of engagement or frustration for instance that in context of performance related parameters provide a richer picture of the patients' cognitive abilities, as any marked changes in their cognition as a consequence of cognitive decline.

6. CONCLUSION

In this paper we report our experience on the design and developing of a game-based stimulation and monitoring system for people with dementia. We considered 7 areas for cognitive stimulation: language, gnosis, executive functions, calculus, attention, memory and orientation. The system was designed specifically for elderly community in Mexico through consultation with psychologists, neuropsychologists, pedagogues, neurologists, graphic designs and software developers. The system was deployed at the Memory Institute which is a unique day therapy centre providing services such as a unique Mental Spa, a Day Therapy Centre, cognitive stimulation programs, and support groups. The system Mente Activa will impact positively in the community, retarding the cognitive degenerative process in an easy and engaging way. Our current and future work is to develop and integrate an evaluation module in order to be able to detect abrupt changes on the performance of the user. This could help us to monitor the patients' cognition, and also the early detection of dementia, in particular Alzheimer.

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