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Scientific evidence for the use of "serious games" or therapeutic games in people with Alzheimer's Disease and other dementias

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Abstract. The progressive ageing of the population, together with the increase in the prevalence of neurodegenerative diseases and the lack of effective pharmacological treatments for Alzheimer's disease (AD) raises the need to seek new therapeutic perspectives. It has been proposed that technology can provide integrated solutions in different areas related to the health and well-being of the patients. In recent years there has been growing interest in the so-called "serious games" or "therapeutic games" aimed at diagnosis or cognitive training in people with Mild Cognitive Impairment (MCI) or AD. The aim of this work is to review the scientific evidence that supports the application of "serious games" in the field of dementia. It presents the concept of "serious games" as well as the objectives and main recommendations in the development of this type of therapeutic games aimed at people with MCI or dementia. It also describes some examples of the implementation of serious games through Information and Communication Technologies. The main benefits and limitations arising from the application of these games in people with dementia are also exposed. We conclude future directions of research aiming to better interventions

Keywords. Serious Games, Alzheimer's Disease, aging, dementia, technology, mild cognitive impairment

1. Introduction

The progressive increase in the percentage of the elderly population worldwide has multiple consequences since it affects our economy, our pensions, our social interactions... In addition, this increase is linked to a significant increase in the incidence of neurodegenerative diseases, which has prompted governments, institutions and social organizations to implement different actions. For example, in 2015 the World Health Organization (WHO) declared dementia to be a global public health priority, promoting the Global Plan of Action 2017-2025, which integrates different areas of action, including diagnosis, treatment, care and support for dementia, as well as research and innovation in this area. This plan reflects the concern for a more comprehensive approach to dementia that addresses the needs of patients, their caregivers and families, reducing the impact of the disease (WHO, 2017).

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On the other hand, we are faced with the limited success of pharmacological treatments developed for Alzheimer's Disease (AD). The available drugs improve some symptoms but there are no treatments to delay the progression of the underlying pathology (Alain, 2018; Webster et al., 2017). Many of the clinical trials that have been carried out in recent years for the development of new pharmacological treatments have failed, so there is a need to take new approaches (Cappa, 2018; Dos Santos Picanco et al., 2018). Several ongoing studies suggest that, in general, one of the best stages for intervention would be the pre-clinical or prodromal phase of the disease. In these stages, technology can play an important role in order to provide integrated solutions in different areas related to the health and well-being of the patients (Doraiswamy, Narayan and Manji, 2018).

It has been suggested that the adoption of new Information and Communication Technologies (ICTs) may have certain limitations in older age groups. However, the user profile is changing and an increasing number of elderly people are using different types of smartphones and other mobile devices. The challenge would be to develop new tools which present easier use for subjects less familiar with the application of new technologies (Zucchella et al., 2014). In fact, various guides encourage professionals to use a variety of technologies with people with dementia, including assistive technology or technology used in commercial games (Van der Roest, Wenborn, Pastink, Dröes and Orrell, 2017). Therefore, the main objective of this paper is to present an updated approach to the scientific evidence supporting the use of therapeutic games based on new technologies in people with AD and other neurodegenerative pathologies.

2. New technologies in the field of aging

In developed countries we live in environments that provide complex and varied stimulation. Different studies suggest that the scarcity or absence of this stimulation can have a negative impact at a physical and mental levels in elderly people, favouring in some subjects a pathological ageing and the development of dementia (Leon and Woo, 2018; McMurphy et al., 2018; Sale, 2018). Recently it has been proposed that the possible effects of environment on health and neuroplasticity should also be taken into account when designing interventions aimed at maintaining brain health throughout life (Bowes and Dawson, 2019; Cattaneo et al., 2018; Clemenson, Gage and Stark, 2018; Sampedro-Piquero and Begega, 2017).

In the field of gerontology, ICTs are being used in older population groups for different purposes. For example, programs based on Ambient Assisted Living (AAL) aim to develop ICT-based interventions that encourage older people to stay at home, promoting independence and personal contact and reducing the costs associated with care. For this reason, it is necessary for professionals working in these fields to be familiar with these projects so that the innovations and solutions developed can be translated to users (Pinazo-Hernandis and Poveda, 2015). In addition, different techniques incorporating the use of virtual reality (VR) have been applied in interventions based on reminiscence for subjects with dementia (Roberts, De Schutter, Franks K and Radina, 2019). The combination of VR with mobile phones offers many possibilities as it allows both auditory and visual stimuli to be presented interactively, providing greater immersion for the user. VR-based applications have been used for diagnosis and treatment in people with cognitive impairment. These tools may have the advantage, over more traditional interventions, of allowing the person to perform activities that are difficult for them to display in their environment (e.g. day center, nursing home or hospital) (Zucchella et al., 2014). ICTs can also make the environments in which these subjects live safer, which would help them to live independently for a longer period of time (Pinazo-Hernandis and Poveda, 2015; Tziraki, Berenbaum, Gross, Abikhzer, Ben-David, 2017).

As Drummond and colleagues (2017) indicate in their recent review on the use of serious games in the field of health, "*new technologies are already invading our world in different fields*".

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Along with this growing interest in ICTs, there has been growing interest in applying the so-called "serious games" or "therapeutic games" that are being applied in different fields (such as education, military training, physiotherapy, mental health...) to interventions aimed at the elderly. Serious games could be considered as an "enriched environment" as they address different domains (cognitive and non-cognitive) and also provide entertainment. Some of these games include physical activity, favouring in many cases social interaction and the expression of positive emotions (Maillot, Perrot and Hartley, 2012). In this sense, "serious games" would include some of the basic characteristics that have traditionally been attributed to models of environmental enrichment in rodents (Clemenson, Gage and Stark, 2018; Redolat and Mesa-Gresa, 2016; Sale, 2018).

3. Delimitation of the concept of "serious games" or "therapeutic games"

3.1. Definition

In scientific literature on the subject, "gamification" is sometimes confused with "serious games". When we use the word gamification we understand that the objective is to create a complete game experience (for example, incorporating some characteristic aspects of game design such as avatars, rewards, feedback on execution...) (Zhang, Ying and Ho, 2018). By "serious games" we mean games that have been explicitly created with a purpose other than entertainment (e.g. education, training in different contexts...) (Lau, Smit, Fleming and Riper, 2017; Michael and Chen, 2005; Zucchella et al. 2014).

The concept of "serious games" was introduced in 2002 by B. Sawyer and D. Rejeski in the book *"Serious Games: Improving Public Policy through Game Based Learning and Simulation"* (2002) and subsequently the use of this term has spread widely in different contexts. For the development of serious games the experts highlight the need to incorporate three fundamental objectives (Bouchard, Imbeault, Bouzouane and Menelas, 2012): 1) We need to converge the extrinsic and intrinsic motivations of potential users; 2) We must rely in the basic pillars of learning in order to enhance the involvement of the subject with the video game; and 3) It should be considered the possibility of evaluating the results obtained using standardized batteries. It has been suggested that the "good serious games" challenge players to feel immersed in the situations that arise in the development of the game.

Sometimes different denominations are used to designate this type of games. When the objective is to improve some aspect of physical or mental health, some authors prefer to speak of "therapeutic games" or when its goal is educational, they are sometimes called "formative games", while when the objective is to prevent cognitive decline, these games are often referred to as "neurogames" (Tziraki, Berenbaum, Gross, Abikhzer and Ben-David, 2017).

3.2. Application of "serious games" in relation to Alzheimer's disease and other dementias In relation to cognitive impairment, it has been pointed out that there is a need to develop reliable ICTs-based instruments that can be used for diagnostic screening and are easy to administer so that they can be used as a complement to the classic "pencil and paper" tests (Bonnechère et al., 2018; Jung et al., 2019). In addition, such tools could help to select the most suitable participants for clinical trials, contributing to a better assessment of treatment responses (Bottiroli et al., 2017) or even the possibility of using digital technologies as biomarkers (Gold et al. 2018).

In a recent review Chinner and colleagues (2018) identified 24 articles detailing different digital technologies, including those based on "serious games", that could be applied to cognitive assessment in later life. Among the main contributions that these new tools can provide, the following stand out: obtaining data with greater ecological validity, contributing to the search for new pharmacological treatments, monitoring patients in the long term and reducing the cost of evaluations (Chinner, Blane, Lancaster, Hinds and Koychev, 2018). Gold et al. (2018) have

suggested that using a game based "interface" can help to reduce anxiety and social isolation in patients with dementia. In the case of patients with dementia, games would allow a more "ecological" evaluation of daily living activities (ADLs) (Valladares-Rodriguez et al., 2018a, b). Recently Vanessa Vallejo and collaborators at the University of Bern in Switzerland developed a "serious game" that recreated 6 real-life situations (going to the store, shopping, going home, cooking, going to the garden, preparing the table) as an assessment tool for cognitive function in patients with AD (Vallejo et al., 2017).

In general, new technologies allow diagnoses to be made and interventions to be proposed in a more standardized, highly stimulating and entertaining environment. In the long term they could even lead to a possible paradigm shift in the field of psychological and neuropsychological research (Pagliarini and Lund; 2018). In recent years there has been growing interest among professionals to design "serious games" aimed at cognitive training in people with MCI or AD with the objective of slowing the decline that accompanies both normal and pathological aging (Anguera et al., 2013; Ben-Sadoun, Manera, Alvarez, Sacco and Robert, 2018; Chi, Agama and Prodanoff, 2017; Kim, Lee and Oh, 2015; Nouchi et al., 2012). There is controversy regarding the use of computerized cognitive training in elderly subjects although recent data support the benefits of this training at cognitive and functional levels (Harvey, McGurk, Mahncke and Wykes, 2018). It has been suggested that the positive effects of "serious games" on cognitive functions such as working memory or attention may be related to brain plasticity (Anguera et al., 2013). Such games, in interaction with brain neuroimaging techniques, may help to better understand how the brain functions in different situations (Robert et al., 2014).

Sea Hero Quest application is an example of serious games that is helping to advance our knowledge of how cognitive losses and spatial learning deficits associated with dementia could develop. Preliminary data obtained with this game suggest that the spatial navigation capability shown by subjects in this VR-based mobile app correlates with its execution in a real-life task based in the orientation along the streets of a city. Since spatial disorientation is one of the first symptoms in AD, it is suggested that such applications could be useful as diagnostic tools in early stages of the disease (Coutrot et al., 2019). Another interesting example of the application of serious games is the AD-GAMING project (http://adgaming.ibv.org/es) based on different premises that derive a large part of the recommendations for the development of "serious games" in the field of dementia and that have been exposed in previous paragraphs (Manera et al., 2017; Muscio, Tiraboschi, Guerra, Defanti and Frisoni, 2015). The project consists of a platform that aims to focus on serious games as an innovative therapy, to promote the direct participation of people with Alzheimer Disease, and to adapt ICTs-based solutions so that the games can be used in different contexts. One of the main characteristics of "AD-GAMING" is the ease of use of the platform by professionals, families and/or caregivers and access to materials and tools for the development of different games. In addition, the information contained in each game details the main cognitive dimensions to be assessed. Access to the platform is free and also includes a methodological guide prepared with the direct participation of users and relatives, as well as interactive tutorials. Validation studies would be necessary in order to test this platform and the games that are included as a complement to other types of non-pharmacological therapies used with these patients.

3.3. Recommendations for the use of games in people with dementia

Research in the field of non-pharmacological therapies shows that people with dementia are more willing to interact with the activities proposed to them if they are adapted to their interests. It is therefore important to take into account the patient's own needs and interests both in the development and implementation of "serious games" (Imbeault, Bouchard and Bouzouane, 2011). In patients with MCI and AD, despite promising results, there is still a lack of studies to

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confirm their efficacy. It would be important to assess "when, where and with whom" serious games aimed at patients with AD and other dementias should be played (Muscio, Tiraboschi, Guerra, Defanti and Frisoni, 2015; Robert et al., 2014). In 2016, within the framework of the 10th World Conference of Gerontechnology, a Delphi panel of experts in the field (including 23 researchers and health professionals) was constituted in which, from the scientific literature, general recommendations were established for the use of "serious games" in patients with neurodegenerative diseases. The results confirmed that serious games can be adapted for people with MCI and dementia with different objectives (evaluation, stimulation, improvement of well-being...) (Manera et al., 2017). Experts recommend that these can be played both at home and in clinical facilities. In addition, the idea that games are most effective when the patient is accompanied by a caregiver/clinic is emphasized, although some games can be used by the patient alone. The frequency of play for each game should be adapted to each subject although in general it is recommended between 2-4 times per week (Manera et al., 2017). Robert et al. (2014) suggest introducing multi-sensory interactions into games. For example, some authors recommend adding music, as this may encourage the subject to interact with the elements of the game. In relation to the development of the games, Bouchard et al. (2012) propose that games should try to create relatively simple scenes that promote ecological interactions, requiring responses based on gestures and not based on complex interactions with the keyboard or mouse of the computer, thus reducing the learning time of the task. Ben-Sadoun et al. (2018) indicate that it is important to evaluate "serious games" in the same population group in which they are going to be used, providing constant feedback about performance. In general, it is difficult in each game to achieve a "balance" between the introduction of elements of novelty or challenge that move the subject forward and the need for guidance that many of them require. It is proposed that the challenges proposed by the game should be adapted to the level of each player so that they can face them independently.

4. Possible benefits and limitations of serious games

From a theoretical point of view, it has been suggested that "serious games" can facilitate learning on the basis of individual needs (Gauthier et al., 2019). Among the advantages of these games, Tziraki and colleagues (2017) highlight that serious games represent low-cost interventions for the care of people with dementia. In addition, they generally require minimal professional supervision as they can be played under the guidance of both formal and previously trained informal caregivers.

According to Dorawaismy et al. (2018) automated cognitive tests may provide individualized measures that are more error-free than traditionally used instruments. In addition, ICTs can be an aid to longitudinal studies that evaluate the conversion from MCI to AD. For example, many activities of daily living (space navigation, telephone or computer use, driving...) can be assessed by sensors, GPS... Some behavioural changes characteristic of AD (wandering, sleep, circadian rhythm disturbances, depression, agitation...) could also be recorded by these instruments.

Among the additional benefits that this type of games can provide, we highlight the idea that they can represent an opportunity for patients to play for fun, but at the same time learn something new. In addition, they can contribute to promoting cognitive stimulation and social interaction in these patients, and in some games also physical activity. The implementation of some serious games may also help in some cases to challenge the public's views on dementia (Van Patten and Tremont, 2018). As research progresses, we will be able to better understand all the possible benefits and opportunities that "serious games" may represent for people with dementia and their caregivers.

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Some authors have also pointed out the possible limitations associated with the use of "serious games" in people with dementia. It has been suggested that more complex tools may require technology or motor or cognitive skills that some participants do not possess and other tools can provoke fear or rejection by some participants (Gold et al., 2018). On the other hand, it has not been clarified how biometric and digital data should be applied in trial and few games have undergone controlled trials (Doraiswamy, Narayan and Manji, 2018). Some authors advocate the inclusion of biomarkers and the need of clinical trials to evaluate the benefits obtained from the implementation of these games in comparison with other types of non-pharmacological therapies (Gold et al., 2018; Muscio, Tiraboschi, Guerra, Defanti and Frisoni, 2015). One of the main limitations for the introduction of serious games for cognitive assessment is the lack of normative data and the fact that in many cases they have been developed without taking into account the opinion of the users themselves (Gold et al., 2018; Valladares-Rodriguez et al., 2017, 2018a). Given the enormous amount of data that can be collected by current instruments (apps, wearable, home automation sensors, personal digital assistants...) in all cases ethical aspects such as privacy, data sharing, informed consent, conflicts of interest must be taken into account... In addition, these technologies entail relevant ethical issues when used in clinical trials, increasing the time and cost of development (Gold et al., 2018).

5. Conclusions and future perspectives

Technology is advancing very rapidly and its application in different fields is expected to improve both the diagnosis and the development of new therapies for AD and other neurodegenerative disorders (Doraiswamy, Narayan and Manji, 2018; Fernández-Ríos and Redolat, 2018). In relation to the use of "serious games" for diagnosis or intervention in the field of cognitive impairment and dementia, the challenge would be to develop games that could be easy to use even by those who have no experience with computers or technology.

It is important to emphasize the idea that interventions aimed at the prevention of AD (Morgan, 2016) are increasingly necessary. As Viña and Sanz-Ros (2018) state at the present time "only prevention makes sense" in the field of dementia study. Initiatives such as the FINGER (Finnish Geriatric Intervention to Prevent Cognitive Impairment) (Rosenberg et al., 2018) and World Wide-Fingers studies with promising results based on a multi-domain intervention demonstrate the need for further research in this direction. Other ongoing initiatives such as the Barcelona Brain Health Initiative (Cattaneo et al., 2018) lead us to develop the idea that intervention based on "serious games" may also be of interest in this area within a broader context. In order to achieve these objectives it would be necessary to bridge the gap that currently exists between "game designers" (who possess the knowledge, methodology and experience with video games) and scientists who provide neuropsychological knowledge on ageing and dementia (Mishra, Anguera and Gazzaley, 2016) although there have been recent attempts at collaboration in this regard. The development of the game "Sea Hero Quest" which aims to assess changes in spatial orientation as a predictor of dementia is a good example of this collaboration (Coutrot et al., 2019).

In future studies it is important to continue evaluating what the real benefits of serious games can be both in the prevention of cognitive impairment and in the field of dementia. Due to the high prevalence of cognitive impairment associated with AD, it is necessary to continue developing new games and to investigate the efficacy and cost-effectiveness of these interventions (Muscio, Tiraboschi, Guerra, Defanti and Frisoni, 2015). As it has been commented throughout the work, the available scientific evidence and the scarcity of adverse effects that these interventions may have encourage further research in this direction.

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