COGNITIVE STIMULATION AND INFORMATION-COMMUNICATION TECHNOLOGIES (ICT) IN ALZHEIMER’S DISEASE: A SYSTEMATIC REVIEW

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ABSTRACT

Cognitive stimulation (CS) is an individualized approach to help cognitively impaired Alzheimer’s disease (AD) patients and their families in identifying personally relevant goals and devising strategies for addressing these. Information-Communication Technologies (ICT) applications can considerably contribute to improve the CS. A deeper knowledge and experience in this field is needed to allow the application of ICT concepts and approaches to the CS treatment of AD. We reviewed the literature and identified systematic reviews of cohort studies, and other authoritative reports. Our selection criteria for CS and ICT in Alzheimer’s disease included: (1) CS, (2) ICT, and (3) AD.

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We identified 154 studies published between 2000 and 2015, of which 9 met inclusion criteria. Most studies reported that older adults with AD need to be technologically savvy in order to successfully complete or benefit from training. All the studies on small samples show that the introduction of ad-hoc ICT tools are accepted, used and could improve the quality of life increasing the permanence at home. From the state of the art point of view some researchers have investigated new solutions for cognitive assistance in the last three years (serious games and robotic systems). The research consisted in exploiting software platform allowing the support of new assistive tools that are less expensive and more accessible and could be used as a re-education tool helping to slow the decline of people suffering from AD.

Most of ICT solutions provided memory challenges and improved brain performances.

**INTRODUCTION**

**Alzheimer’s disease (AD)** is a chronic neurodegenerative condition characterized by a progressive deterioration of cognitive function. AD is the most common form of dementia [1], and, currently, there is no effective disease-modifying cure and treatment is intended only to manage the symptoms [2].

Such circumstances entail severe social consequences regarding growing family burdens, lesser quality of life and well-being, increasing health care demand, longer term utilization of care facilities, and so on, all of which generate very significant impacts on health care services demand and costs [3]. Memory impairment is one of the main cognitive issues that contribute to inability to live independently [3, 4, 5]. Memory impairment in the early stages of AD limits memory processes and reduces older people’s autonomy when performing more complex daily activities. It concurrently causes deterioration of emotional control, social behavior, and motivation [3, 5]. AD represents one of the major causes of disability and dependency among older people worldwide.

The World Health Organization (WHO) reported that in Europe and the Americas peak incidence of AD is among those aged 80-89 years, in Asia it is among those aged 75-84 years, and in Africa among those aged 70-79 years [6]. The researchers estimated nearly 7.7 million new cases of dementia each year worldwide, implying one new case every 4 seconds. Of these new cases 3.6 million (46%) would impact in Asia, 2.3 million (31%) in Europe, 1.2 million (16%) in the Americas, and 0.5 million (7%) in Africa [6].

In AD, the pharmacologic treatment delivers limited symptomatic benefits [7, 8], so the provision of **non-pharmacological treatments** in addition to standard outpatient care is an asset of good clinical practice.

Several non-pharmacological treatments targeting cognition and functionality have been proposed for patients with AD [9, 10, 11, 12]. Among possible cognition-focused interventions for people with dementia, the **Cognitive stimulation (CS)** is an individualized approach to help cognitively impaired older and their families in identifying personally relevant goals and devising strategies for addressing these [13], with emphasis not on performance enhancing on cognitive tasks as such, but on improving functioning in the everyday context [14]. In a recent study, the integrated treatment of Rivastigmine transdermal patch (RTP) with CS in AD patients for 6 months improved significantly cognition,
depressive and neuropsychiatric symptoms, functional status, and mortality risk in comparison with a group of AD patients receiving only RTP [15].

Development and implementation of novel computer-based Information-Communication Technologies (ICT) applications in the field of cognitive impairment mitigation and rehabilitation can contribute to address the research. Emerging ICT applications based on virtual reality (VR) environments, including Augmented Reality technology, can become important game changers. The ICT may provide promising new tools to improve the functional and cognitive assessment of patients with AD and related disorders [16].

A deeper knowledge and experience in this field is needed to allow the application of ICT concepts and approaches to the CS treatment of AD.

**METHOD**

Literature searches were conducted in the MEDLINE (2000 to July 2015) and PUBMED (2000 to July 2015) databases, using the OVID search interface. The search queries included (1) Cognitive stimulation (CS), (2) Information and Communication Technologies (ICT), and (3) Alzheimer’s disease (AD) and were limited to human studies. Only English language articles were included, due to lack of resources for translation. Reference lists of included articles and relevant review articles were examined to identify any studies which the electronic search strategy may have missed.

**Study Selection and Assessment of Methodological Quality**

A single reviewer examined abstracts retrieved by the electronic search to identify articles meriting a full review. Full length articles were then reviewed before data were extracted from relevant papers.

The inclusion/exclusion criteria used for our review protocol are the following.

Inclusion criteria were: 1) age ≥60 years; 2) diagnosis of AD according to the criteria of the National Institute on Aging-Alzheimer's Association (NIAAA) [17], 3) use of CS with ICT tools to investigate disease improvement in AD, and 4) acceptable clinical measures of cognitive impairment, disability, quality of life, and global clinical assessments.

Exclusion criteria were: 1) no English editing (because we had no resources for translation), and 2) diagnosis of non-AD dementia.

No restrictions were made on the grounds of disease duration or drug treatment.

As well as describing test accuracy, an important goal of the diagnostic test accuracy (DTA) process is to improve study design and reporting in dementia diagnostic studies. For this reason we assessed both methodological and reporting quality.

Quality of study reporting was assessed using the Standards for the Reporting of Diagnostic accuracy studies in dementia (STARDdem) [18].
RESULTS

Initially, 154 studies published between 2000 and 2015 were deemed relevant to the current review. Each study was reviewed and information pertaining to the study design, sample characteristics (e.g., age, cognitive status), cognitive outcomes, and the means and standard deviations of cognitive tests before and after training in the experimental and control groups were extracted.

Based on the stated inclusion and exclusion criteria, 9 of the 154 publications were eligible for the current review (Figure 1).

Current Use of ICT in CR

The characteristics of research outcomes are summarized in Table 1.

The first study, entitled AL.TR.U.I.S.M. (Alzheimer patient’s home by a rehabilitation-based Virtual Personal Trainer Unique Information System Monitoring) – funded by Apulia Region under the health care call for the promotion of regional partnerships for innovation and driven by an aggregation of SMEs -, developed a remote system, called “Virtual Personal Trainer,” integrating an advanced Natural User Interface technology that is able to support the patients at home during the rehabilitation process [19]. The system allows both the autonomous execution of the required exercises and the data reporting and storing concerning the daily performance of every exercise. In this scenario, the patient avoids to physically move to a specialized center and the physician can use the platform in order to verify the response to the therapy and the compliance to the treatment.

Another study examined the acceptability of ‘Kitchen and cooking’ – employing a serious game (SG) developed in the context of the EU project VERVE - for elderly people with mild cognitive impairment (MCI), AD, and related disorders [20]. In this game a cooking plot was employed to assess and stimulate executive functions (such as planning abilities) and praxis. The game was installed on a tablet, to be flexibly employed at home and in nursing homes. Interestingly, the results confirmed that the game is adapted also to apathetic patients.

SG based cognitive and motor performance profiles while performing everyday activities and dual-task walking (DTW) “motor signatures” are two very promising markers that can be detected in predementia states.

The study [21], compared the consistency, or conformity, of measurements made by a custom SG with DTW called NAV with another SG without DTW, called DOT. The measurements involved in the test are neuropsychological measures and genotyping as markers for early detection of amnestic Mild Cognitive Impairment (aMCI). The findings suggested that “motor signature” data during the NAV tasks constituted a more reliable marker for early diagnosis of aMCI than DOT. This result accentuates the importance of utilizing motor performance data as a metric for aMCI populations where memory decline is often the behavioural outcome of interest. So, custom SG with DTW performance data provides an ecological and reliable approach for cognitive assessment across multiple sessions and thus can be used as a useful tool for tracking longitudinal change in observational and interventional studies on aMCI.
Figure 1. Flow diagram outlining the selection procedure to identify articles which were included in the systematic review of Cognitive stimulation and Information-Communication Technologies in Alzheimer’s disease.
Table 1. Current use of Information and Communication Technologies in Cognitive Rehabilitation

<table>
<thead>
<tr>
<th>Studies</th>
<th>Methods</th>
<th>Outcomes</th>
<th>AD (N)</th>
<th>MCI (N)</th>
<th>Control (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caroppo A. et al., 2013</td>
<td>AL.TR.U.I.S.M.</td>
<td>Positive attitude towards innovative technology solutions</td>
<td>72</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Manera V. et al., 2015</td>
<td>SGs</td>
<td>The game is adapted also to apathetic patients</td>
<td>12</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Tarnanas I. et al., 2015</td>
<td>SGs</td>
<td>Motor performance is a metric for aMCI populations</td>
<td>86</td>
<td>65</td>
<td>76</td>
</tr>
<tr>
<td>Serino S. et al., 2015</td>
<td>VR</td>
<td>Exploiting the potentiality of VR for amnestic impairment.</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Lancioni G.E. et al., 2015</td>
<td>CMVR</td>
<td>Viable solutions for promoting independent verbal engagement/reminiscence</td>
<td>16</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Crawford T.J. et al., 2015</td>
<td>Em</td>
<td>Effects of dementia on oculomotor control</td>
<td>25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Valentí Soler M. et al., 2015</td>
<td>NAO, PARO and DOG</td>
<td>Improvement in apathy and quality of life</td>
<td>20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Span M. et al., 2015</td>
<td>DecideGuide</td>
<td>Increase in helping members engage with one another constructively</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maribel Pino et al., 2015</td>
<td>SAR</td>
<td>Support in cognitive, functional, social, clinical status and quality of life</td>
<td>7</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>


The study [22] has compared the performances of patients suffering from aMCI, patients with AD and a control group (CG), using a virtual reality (VR) based procedure for the assessment of abilities in encoding, storing and syncing different spatial representations [22]. The procedure consists of two tasks. In the first task, participants were required to indicate on a real map the position of the object they had memorized. In the second task they were invited to retrieve the position of the same object in an empty version of the same virtual room, starting from a different position. The entire procedure was repeated across three different trials, depending on the object location in the encoding phase. The findings provided an initial insight into the cognitive underpinnings of amnestic impairment in aMCI and AD patient exploiting the potentiality of VR.

Another study was focused on the assessment of a computer application recently developed for helping patients with moderate Alzheimer’s disease engage in computer-mediated verbal reminiscence [23]. The data showed that 15 of the 16 participants with AD had a clear and lasting increase in verbal engagement/reminiscence. The results of this study suggested that the use of this computer application might be a viable solutions for promoting independent (i.e., computer mediated) verbal engagement/reminiscence in persons with moderate Alzheimer’s disease.
A longitudinal study of saccadic Eye movements (Em) in a sample of patients with AD was the focus of the study [24]. The study involved a group of patients with AD disease and an elderly control group with an assessment at the start of the study and a 12-months follow-up. Em were measured in the standard gap and overlap paradigms, to examine the longitudinal trends in the ability to disengage attention from a visual target. These findings pointed out the value of longer-term studies and follow-up assessment to ascertain the effects of dementia on oculomotor control.

A controlled study of parallel groups of nursing home patients comparing the effects of therapy sessions utilizing a humanoid robot (NAO), an animal-shaped robot (PARO), and a trained dog (DOG), with conventional therapy (CONTROL) on symptoms of dementia is reported in [25]. Patients in the robot groups showed an improvement in apathy while patients in NAO group showed a decline in cognition as measured by the MMSE scores, but not the Severe Mini Mental State Examination (sMMSE). The robot groups showed no significant changes between them. Quality of Life Scale (QUALID) scores increased in the PARO group.

DecideGuide is an interactive web tool that has been developed for facilitating shared decision-making in dementia-care networks [26]. The Decide Guide provides a chat function for an easier communication between network members, a “deciding together” function for step-by-step decision-making, and an individual opinion function for eight dementia-related life domains. The study participants found the web tool valuable in the decision-making process. The chat function seems to be powerful in helping to constructively engage members with one another. Such engagement is an important prerequisite for making shared decisions.

Socially Assistive Robots (SAR) [27] is an emerging form of assistive technology encompassing all robotic systems capable of providing assistance to the user by means of social interaction. SAR can deliver help at different levels:

A. supporting user’s cognitive or functional abilities (e.g., task reminding and monitoring, navigation aids);
B. offering the user opportunities to enhance social participation and psychological well-being (e.g., communication and social applications, telepresence, companionship);
C. providing remote and continuous monitoring of user’s health status (e.g., blood pressure or fall detection sensors);
D. coaching the user to facilitate the promotion of healthy behavior and achievement of health-related goals (e.g., improving nutrition, physical activity).

The therapeutic use of SAR in the context of dementia care has received increasing attention over the last decade as illustrated by a growing body of research in this area [28, 29, 30, 31].

**CONCLUSION**

This review has identified a range of available assistive technologies that with further interdisciplinary research and modifications may have potential applications to AD care.
In order to progress in the validation of the treatments for AD, better outcome measures for cognitive and functional changes are acutely needed in the earliest stages of the pathology [32]. While some progress has been made in developing intelligent assistive devices that may find applications in dementia care, daunting computational and ethical challenges remain. The dialogue that has ensued over the last decade regarding the role of assistive technologies in modern healthcare is reflected in the rapidly increasing numbers of publications, and conferences and workshops that are specifically devoted to this topic. Moreover, there is a proliferation of research “smart homes,” academic and industry-based laboratories focused on computational models of human activity, behavior and cognition, and the formation of the Alzheimer’s Association Working Group on Technologies. Commercial products that result from these endeavors will be arriving en masse in the coming years, and it will be important for clinical researchers to critically evaluate their performance characteristics and utility in “real world” settings. Academic interest in this area has also led to increased attention to developing national funding mechanisms that would specifically consider interdisciplinary technology research applications so that these do not fall through the cracks of existing agencies [33]. Finally, however, the use of technological innovations in this field is becoming a reality.

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