CogAR: an augmented reality App to improve quality of life of the people with cognitive impairment

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***Abstract*— The number of people affected by dementia in the world is growing up due to the shift of the population age profile. This paper presents a tool to help and support people who suffer from both cognitive decline age-related and cognitive impairments. Cognitive impairment refers to a person who has trouble remembering, learning, concentrating, or making decisions that affect their daily life. Cognitive impairment varies from mild to severe. With mild impairment, people may begin to notice changes in cognitive functions, while still be able to do their everyday activities; on the other hand, severe levels of impairment can lead to losing the ability to understand the meaning or importance of something in addition to the ability to talk or write, resulting in the inability to live independently. We developed an augmented reality home-made App, CogAR, designed for smart glasses. The App can be a useful tool able to provide more independence to patients during actual daily living activities and in navigating their home, providing cues for memory integration in real time. In this way, elderly people, could stay at home longer without the need to move into a care home environment.**

Keywords—cognitive impairment, augmented reality, smart glasses

I. Introduction

Cognitive impairment occurs in a continuum, starting with aging-related cognitive decline followed by transition to mild cognitive impairment status, and ultimately to dementia. Mild cognitive impairment does not substantially affect daily function, whereas dementia causes cognitive changes that are potentially severe enough to affect daily function [1] (Fig. 1).

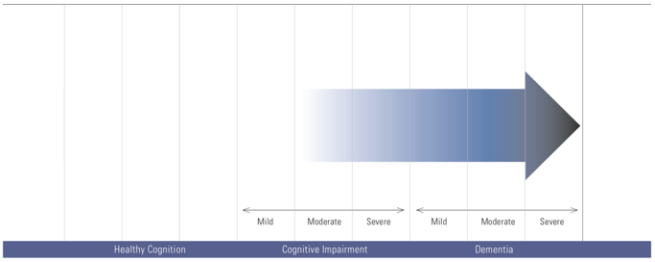

Fig. 1. An individual's progress from healthy cognition to dementia is a continuum. The transition from healthy or normal cognition status to cognitive impairment is not distinct, but blurred. Similar transitions occur between cognitive impairment and dementia. [2]

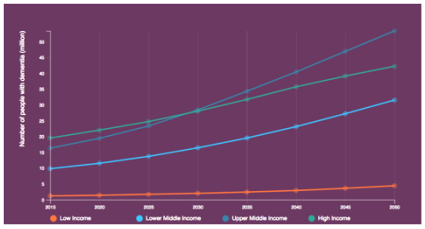

Fig. 2. Evolution of patients' number affected by dementia from 2015 to 2050. The countries are ranked in 4 classes based on their income (low, lower middle, upper middle and high).

As age progresses, in each person a change in his/her brain structure and functions occurs which can provoke a cognitive decline [1]. Cognitive age-related decay involves several symptoms, such as deficits in memory, reduction in level of attention and concentration as well as planning, problem solving and in executive functions [3]. Deficits in executive functions increase the need for help while carrying out activities of daily living (ADL) [4].

All around the world, about 46 million people suffer from dementia. The increase in life expectancy has led to a significant aging of the population and so this number is set to increase to 131.5 million by 2050 [5] (Fig. 2).

People with cognitive impairment are reported as being three times more hospitalized compared to individuals who are hospitalized for other conditions [6]. In many developed countries healthcare cost has overtaken those related to cardiovascular disease and cancer [7].

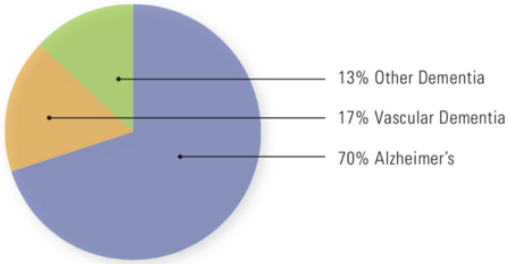

Fig. 3. Causes of Dementia in people aged 71+. [2]

A. Causes and signs

Dementia is characterized by loss or decline in memory and other cognitive abilities [2]. There are over 100 forms of dementia and the most well-known is Alzheimer disease (AD) [8] (Fig. 3). Considering patients with AD, an estimated 4% are under age 65, 6% are 65 to 74, 45% are 75 to 84, and 45% are 85 or older [9]. However, other conditions such as stroke, traumatic brain injury, and developmental disabilities, may cause cognitive impairment [6].

One of the first stages of AD is Mild Cognitive Impairment (MCI), and over time MCI patients are considered at higher risk for dementia [10]. The most common symptom correlated with MCI subjects is the impaired episodic memory; moreover, subjects diagnosed with MCI are associated with a decrease of quality of life and self-esteem, as well as greater social isolation for both categories, patients and their caregivers [4].

A few common signs of cognitive impairment include the following [6], [9]:

- Memory loss that disrupts daily life
- Frequently asking the same questions or repeating the same story over and over.
- Not recognizing relatives or siblings and places.
- Reduced or poor judgment in decision making situation such as how to behave in an emergency.
- Changes in mood or behavior.
- Having issues understanding visual images and spatial orientation.
- Difficulty planning and carrying out tasks, such as following a recipe or keeping track of monthly bills.
- constantly increased problems with words during speaking or writing.

B. Intervention programs

The increase of the number of people with cognitive impairment demands to identify a methodology able to detect the decay of cognitive function in an economic and easy way [11]. Studies have focused on the development of efficient treatment strategies.

Elderly people should train their cognitive and motor skill on a daily basis. It is advisable for them to carry out the following activities: physical exercises (e.g., walking), take care of their own house, reading, playing musical instruments, taking part in social events and group activities (e.g., playing cards), learning new skills [12]. In fact, the risk of dementia increases with a lower participation in leisure activities carried out by the person [13]. Previous studies highlighted that consistent physical and social activities help maintaining neuronal plasticity and help increasing brain activity of the elderly people [14], [15], [16], [17], [18], [19].

At this moment, AD has no cure [8]. Currently, to mitigate the effects of cognitive decline, most common interventions are based on medications' administration [20]. However, it has been also reported the benefit of non-pharmaceutical intervention in elderly [10].

Various non-technological solutions aimed to support elderly people in ADL have been proposed, such as the use of a diary [21], or the modification of the physical environment by removing cabinet doors or employing clear plastic on drawer folders [22].

One of the best ways to maintain the functionality of people in an old age state for the longest possible period is to mitigate the degeneration by stimulating cognitive and physical functions [18]. Cognitive training exercises have been shown to slow down cognitive decay ratio and potentially even reversing it (e.g., [23]), however, the traditional programs of psycho-stimulation have several aspects that make their application difficult, such as high load in human and financial terms [12]. The use of Information and Communication Technologies (ICTs) in this area allows, in principle, to overcome these disadvantages [12]. Hence, as an example of application of ICT tools, researchers considered to evaluate the effectiveness of Serious Games as a training tool for cognitive abilities, obtaining satisfactory results in terms of cognitive and attention skills, reaction times, and a sense of well-being while playing computer games ([3], [12], [24], [25], [26], [27]). Several studies focused on the use of Virtual Reality (VR) ([3], [12], [25], [28], [29], [30]). Serious Games and VR experiences allow users to face situations similar to those encountered in real life, but with complete safety, control and low-cost environment [3]. In this way, therapists can assess patients' performance.

The artificial nature of laboratories enhances the internal validity but reduces the ecological validity aspect. Traditional measures in lab, being out of the context of real life, could limit the elderly performance and improvement by avoiding the benefit of the experience and the confidence gain expected by a familiar context [31]. The advancement of technology results in the possibility of supporting the people with cognitive impairment in their own house [4]. By bringing technology in each user's daily life, this changes the type of the assessment: from short and episodic monitoring to continuous and real time evaluation. Several technologies have been studied with the purpose of supporting people during ADL. These ranges from single simple prompts [32], [33], [34] to more complex input sequences [35], [36]. A solution is offered by Smart Homes, that allows to control patient's health status and detect specific events, such as falling [11], [37], [38], [39], [40]. Smart Homes can offer an evaluable environment, efficient from an ecological point of view [39]. The disadvantage is the demand of many sensors, which is generally associated with a high financial expense.

A cheaper solution is the use of wearable sensors such as Head Mounted Displays (HMDs) for augmented reality. HMDs are rapidly evolving. In the last decade there have been great improvements both from the point of view of design and portability, and from the point of view of technology in terms of display-type (from *Poly-silicon TFT active matrix* to *Mono Crystalline Silicon Active Matrix*) , pixel number (from 518,400 to 921,600 pixels) and refresh rate (from 60 to 30 Hz).

The HMD devices could be an efficient tool to hinder the cognitive decay of elderly people. Augmented reality (AR) is a technology where a user's view or vision of the real world is enhanced or augmented with additional information generated from a computer model. The AR interface can decrease the cognitive load [32], [33], [34], [36], [41], [42]. In fact, elderly people are prone to use mental representations to enhance short-term memory [34]. In comparison to VR, AR is considered more user friendly, since it does not isolate the user from his/her environment. Furthermore, AR technology allows to combine both cognitive with physical exercises.

Fig. 4. The commercial HMD used in this study.

For these reasons, we have decided to develop an AR marker-based Application, CogAR, to assist patients in their ADL – at home and also away from home. The AR system aims to show (symbolically and/or textually) the hidden spots, such as rooms behind doors or objects in the cupboards, and to warn that a contact with an object may be dangerous, such as electrical sockets, stoves, ovens or other house utilities [43].

This proposed tool mainly targets subjects who are living alone: about one-third of all people with dementia are living on their own [44]. They are considered a particularly vulnerable group, at an increased risk for unmet social, environmental, psychological and medical attention.

II. Materials and Methods

Android is a mobile operating system designed primarily for smart devices. CogAr is an Android marker-based augmented reality App developed for a commercial HMD.

A. Set-up

To be run, the App requires only the HMD device and a printed image (marker) which we have associated with augmented information (Augmented Object, AO) via software. The HMD is equipped with a series of integrated sensors, including a camera embedded on its right side (Fig.4). In order to program the markers that can be recognized by the HMD and to associate each of them with an AO, we used Unity 3d, a cross-platform game engine, and a plugin provided by the HMD's manufacturer. The plugin allows you to choose and upload specific 2-D images or 3-D models that will act as markers. Through Unity it is possible to associate each of these markers with an AO, positioned close to the marker, which can be represented by a customizable image, text or multimedia content (audio or video).

B. User interface

When the user wears the HMD, he experiences the surrounding real-world environment while the software is generating visual elements that are overlaid on the real-life visualization [8]. We set specific markers on the physical objects of interest, as suggested by the National Institute on Aging (USA) [43]. Each of these markers is associated to a particular AO (text, picture, …), which can be programmed based on the subject's preferences and needs. When a marker falls within the camera's field of view, the system shows the AO to the user, overlaid on the marker position.

Furthermore, we decided to show on top of the screen of the HMD the fundamental user contacts (i.e.: police, ambulance and caregiver telephone number). Thus, if the user needs it, he/she can easily reach the emergency contact (e.g., police, ambulance or caregiver) handy.

Finally, thanks to the camera being always active while the application is running, and to a free of charge mirroring App available in PlayStore ("WiFi-Display(miracast)"), which allows to share the user's field of view, the caregiver has the possibility to check at any time the patient's activity from his/her smartphone and therefore the ability to quickly identify potentially dangerous situations.

Fig. 5 and Fig. 6 explain two examples of the CogAR. The top panel of each figure shows the users' field of view when he/she puts on the HMD and the marker is out of the camera's field of view; on the bottom panel, the camera identifies the marker and the associated augmented objects are shown.

Fig. 5. The marker is applied on the entry door of the subject's house (top); when the user looks at the marker, through the HMD, information that recalls his/her own home are shown (bottom)

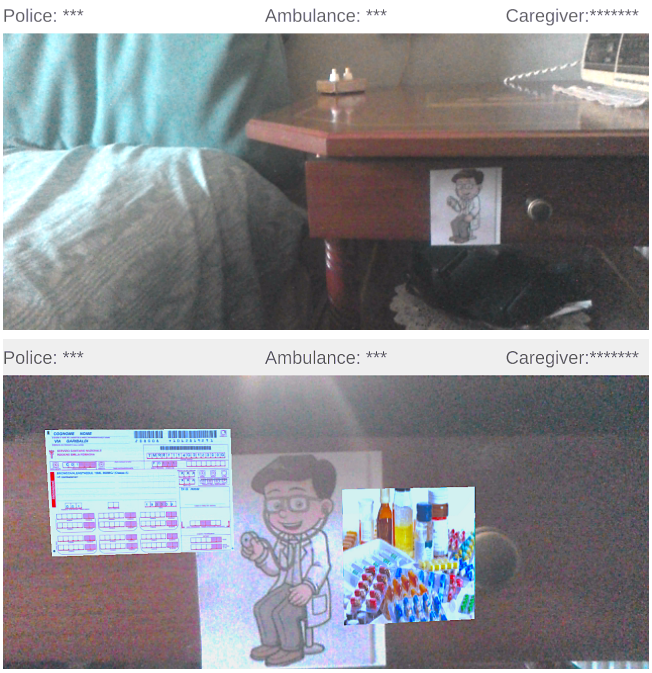

Fig. 6. The marker is applied on the bedside table where the user keeps the medicines (top); the view through the HMD when the user looks at the marker that shows the contents of the drawer (bottom)

III. Conclusion and Future Work

The AR-supported home environment can be useful for patients while navigating the home itself, providing cues for memory integration. This patient empowerment should lead to an improved confidence during ADL and, ultimately, a higher degree of physical activity. The possibility provided by the AR to merge cognitive exercises with physical activity is expected to make the support intervention more effective. In fact, increasing level of physical activity has now been identified with certainty as a protective/preventive factor against the progression of neurodegenerative diseases [14], [19].

Elderly people may find difficult accessing and using technology as well as facing deficits in learning new information. This would limit the ability of persons with dementia to acquire the conceptual knowledge needed to interact with a novel interface. Furthermore, impaired attentional control would also disrupt their ability to adopt unfamiliar procedures.

The tool presented in this paper could enhance the quality of life of elderly people breaking down these barriers for the following reasons:

- No need to learn new skill
- Any input device or button to be pressed is not required
- It is possible to know where any object is located, without the need to open all the doors or all the drawers, un-necessary movements are limited and so the environment becomes safer.

Therefore, we are confident that our system could meet the criteria of compliance (always having the device by hand), dignity and usability. With the purpose to assess the latter, we plan to carry out an experimental study, initially involving elderly healthy people.

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