Can Cognitive Assessments be Fun? A Review of Playful Mobile Applications to Assess Cognitive Health

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Abstract
Due to the increasing average lifespan in economies all over the world the proportion of older members of society increases to grow. Older people are specifically prone to a cognitive decline due to Alzheimer's Disease or related forms of Dementia. Although there is currently no medical cure available, early detection of Dementia would enable earlier treatment with medication to postpone the outbreak which enables the person to have a longer self-sustained living. The application of new information and communication technology is a growing body of research this area. Initial results indicate that serious games and playful mobile applications are able to improve cognitive and physical health areas of people who are affected by Alzheimer's Disease or other Dementias. However, less is known about their potential to detect the cognitive decline. This paper provides a structured overview of published to employ mobile applications with playful elements to assess the cognitive health of the user. Existing applications are identified and analyzed for the specific type of cognitive stimuli they are addressing.
Keywords: Elderly People, Cognitive Assessment, Mobile Applications, Gamification, Dementia

Introduction
Dementia is a general term for neurocognitive disorders which are characterized by occurring damages of nerve cells in the brain. Alzheimer´s Disease (AD) is the most common cause of these damages, which are irreversibly (Alzheimer´s Association, 2016). AD manifests in a decline of cognitive and psychological functions. The cognitive decline refers to memory, speech, language, judgement, reasoning, planning, confusion and other thinking abilities. Psychological functions include symptoms like depression, apathy, behavior changes and withdrawal from social activities (Alzheimer´s Association, 2016).
In 2015, about 46.8 million people worldwide were estimated to have Dementia, whereby forecasts predict further increases in the next decades because of increasing average lifespans of the populations (Alzheimer´s Disease International, 2016; Robert et al., 2014). This development rises to a challenge for literally all developed economies due to the emerging costs for the health systems and societies (Prince et al., 2015). Apart from direct cost of healthcare, the side effect that the person is unable to live on her-/himself anymore affect society as either relatives have to take care or professional caregivers are needed. The latter are in short supply, specifically in highly developed societies.

Early detection of the cognitive decline would enable earlier treatment and as such could lead to specific medication which could postpone the outbreak of the disease. However, it proves difficult to find robust early detection mechanisms (Iliffe et al., 2002). Current cognitive screening tests like the Mini-Mental State Examination (MMSE) (Folstein, 1975) or the Montreal Cognitive Assessment (MoCA) (Nasreddine, 2005) are standardized tools to assess cognitive health. Though, these methods do not create engagement or entertainment for the patient (Tong, Chignell, Lam, Tierney, & Lee, 2016) leading to high dropout rates as people are getting bored. Recent approaches try to improve the detection process using information and communication technologies (ICT) instead of traditional pen and paper or computerized screening tests (Boletsis and McCallum, 2016; McCallum and Boletsis, 2013b). Playful elements in applications or serious games are a new method to address the lack of users' motivation (Tong et al., 2016). Serious games have the primary purpose to provide education or training to the user instead of entertainment intentions (Charsky, 2010).

Thus, it seems the logical next step to use modern ICT combined with serious gaming concepts to provide cognitive testing which users intrinsically like doing, instead of getting bored quickly (and consequently stop using it). It needs to be kept in mind that cognitive tests are not one-off but need to be repeated periodically and indefinitely to detect a cognitive decline.

This paper investigates the current state of published work in this area. We provide an overview of the applications to test for ongoing cognitive decline which are available to the public and assess the extent to which these applications use gamification concepts. At the time of writing, six applications were publicly available and documented.

The paper continues by reflecting the fields current state of knowledge on gamification and serious gaming in cognitive assessment software. Further on the method of research is explicated and results are drawn. The paper closes with stating its limitations, providing routes for further research and a discussion.

Current State of Knowledge

Research on ICT in healthcare is a growing area. Mosa et al. (2012) provide a systematic review of healthcare application for smartphones, whereby the majority of applications are directed to healthcare professionals or nursing students. Only a few apps are patient-centered (Mosa et al., 2012). McCallum & Boletsis demonstrate in their taxonomy of serious games in 2013, that no game for the purpose of assessing cognitive functions could be identified at that time (McCallum and Boletsis, 2013b). Instead, mobile applications and serious games referred to rehabilitative purposes. Initial results demonstrate, that they are able to improve cognitive and physical health areas of elderly people who are affected by AD or similar disorders (McCallum and Boletsis, 2013a).

Although, the game-based cognitive assessment on mobile devices represents an opportunity to increase the accessibility for elderly people, little is known about serious games or playful applications on mobile devices that have a diagnostic purpose instead of rehabilitation. To address this lack in research, this paper aims to provide a structured overview of efforts to develop mobile applications targeting the detection of a cognitive decline. In order to contribute to the actual knowledge, the identified applications will be analyzed for the specific cognitive stimuli that is addressed.

Method

In order to provide an overview of efforts in deploying mobile applications with serious games or playful elements to cognitive assessment, a keyword search on scientific databases was conducted. Since this research aim affiliates with several disciplines, multiple databases

from different disciplines were included: Health Management Database, PubMed Central, ACM Digital Library, EBSCOhost and Emerald Insight.
The search was conducted using the following keywords “Older Adults” OR “Elderly” OR “Seniors” AND “cognitive” AND “assessment” OR “diagnosis” AND “game” OR “application” OR “mobile” OR “smartphone”.

Table 1 Longlist of potentially relevant literature

	Health Management Database	**PubMed Central**	**ACM Digital Library**	**EBSCO**	**Emerald**
Dementia and Applications	8,722	28,932	59	115	1,044
Alzheimer´s Disease and Applications	9,981	14,233	30	3	228
Smartphones and older adults	385	2,134	18	12	103
Dementia and serious game	503	603	6	-	51
Alzheimer´s Disease and serious game	349	145	-	-	19

Following Webster and Watson (Webster, 2002), the inclusion and exclusion criteria for articles need to be defined in first place. This paper focuses on mobile applications, which are serious games or offer playful elements, targeting elderly people that aim to detect an early cognitive decline. Articles dealing with these kind of mobile applications were included. For the hits on the scientific databases, the abstracts of the articles with suitable titles were screened. All abstracts dealing with AD&D diagnosis through serious gaming have been chosen for a deeper analysis. These articles were read in detail.
Numerous articles were excluded because they were missing one of the aspects serious game or playful elements, missing effort for detecting cognitive decline or missing mobile devices like a smartphone or tablet. The remaining articles served as basis for conducting a forward and backward search to further identify mobile applications. The final set of articles was used for a deeper analysis.

Results

The literature review yielded six mobile applications for the research purpose of this paper These are discussed in detail in the following. The applications are aligned to their specific cognitive stimuli that are intended to be measured and assessed. Based on what is acknowledged in the current literature, the cognitive areas memory, speech, language, judgement, reasoning, planning, confusion and other thinking abilities. Furthermore, people tend to have problems to process visual impressions quickly and weaken in the ability to inhibit the own behavior (Alzheimer´s Association, 2016; Christ, 2001).
Therefore, these cognitive stimuli have been chosen for this overview, whereby the elements speech and language were summarized to “Language” and judgement, reasoning and planning were summarized to “Thinking abilities”. The results are displayed in table 2 below

Table 2 Results

Application	Reference	Cognitive Stimuli						
		Language	Memory	Orientation	Thinking Abilities	Visual processing	Attention	Inhibition Ability
Smartkuber	McCallum and Boletsis (2016)	x	x		x	x	x	x
Color-Shape Test	Brouillette et al. (Brouillette 2013)						x	
Sea Hero Quest	Deutsche Telekom (2017)		x	x				
Whack-a-mole	Tong et al. (2016)							x
Alzheimer'sDisease Pocketcard	Alzheimer's Association (2018)	x	x	x	x	x		x
Episodix	Valladares-Rodriguez et al. (2017)		x					

Smartkuber can be played on computers and on mobile tablet devices. The application offers a pool of five mini-games. They consist of numerical calculations, finding words, repeat patterns, reconnect to old friends and reconstruct flags. Due to the multiple game approach, lots of different cognitive functions are addressed (Boletsis and McCallum, 2016).
The second identified application is the **Color-Shape Test**. This application is designed for smartphones. The users have to choose quickly correct colored pads displayed that correspond to a predefined legend on the top of the screen. The test addresses the cognitive processing speed (Brouillette, 2013).
In **Sea Hero Quest** users navigate through a maze while shooting with flare guns. Users have to memorize a map and find the correct way through the world. The game addresses orientation skills. The application can be played on smartphones. In the most recent version of the game, virtual reality extensions are offered (Deutsche Telekom, 2017).
Whack-a-mole was developed in the Interactive Media Lab at the University of Toronto. The game features the well-known psychological Go, No-Go discrimination task, which was converted into the game. The cognitive stimuli inhibition ability is addressed within this task (Tong, Guana, Jovanovic, Tran, Mozafari, Chignell, & Stroulia, 2015; Tong et al., 2016).
The **Alzheimer´s Disease Pocketcard** App is an application that provides information and assessment tools to the users. The aim is to help users understand, diagnose, prevent and curing AD. The app has cognitive assessment tools integrated: Clock drawing, GPCOG, MIS, Mini-Cog Test, Montreal Cognitive Assess Tool, SLUMS (Alismail et al., 2017; Alzheimer's Association, 2018).
Episodix is a video game where the users make a virtual walk around a medium-sized town, but it can be played on other touchable devices like tablets. The challenge is to recall the maximum number of elements displayed, while trying to avoid objects in the interference lists. The collection of bonus points provides feedback to the user (Valladares-Rodriguez et al, 2017).

Discussion

The literature research yielded only a very small number of mobile applications which aim to playfully assess the cognitive functions among elderly people. Taking a closer look at the

individual applications, none of them is able to provide a robust detection mechanism in the current version. Instead, they illustrate first efforts to collect the necessary data and improve the applications to pursue the purpose in the future. The majority of them focus on the cognitive function memory, whereas the other categories are addressed less.
Smartkuber revealed sufficient correlations with the acknowledged MoCA screening test. The software roll-out provides valid results. However, some weaknesses in the game difficulties and textual elements could be identified (Boletsis and McCallum, 2016). The color-shape test also proved to be reliable and valid to measure the cognitive functions processing speed and attention, but some problems occurred on the relatively small smartphone screens (Brouillette, 2013). Sea Hero Quest has already produced enormous amounts of research data (University College London, 2016). Results show that orientation impairments appear earlier than memory problems (Deutsche Telekom, 2017). Whack-a-mole proved to be valid to measure cognitive assessment in terms of inhibition ability (Tong et al., 2015). The Alzheimer's Disease Pocketcard provides a very sufficient level of validity and reliability because numerous acknowledged cognitive assessment tests are integrated. On the other hand, the usage needs to be assisted by healthcare professionals. Consequently, the patient is not able to use the app independently (Alzheimer's Association, 2018). In contrast to the other applications, Episodix is focused on one cognitive stimuli only, the episodic memory. Initial results indicate a successful implementation of an assessment tool for episodic memory. However, additional studies will be necessary to further validate the digital game. The developers have gamified the California Verbal learning Test and considered reliability and validity measures (Valladares-Rodriguez et al., 2017).

Limitations and Further Research

The scope was limited to mobile (i.e. smartphone and tablet) applications because elderly people can handle both devices (Kurniawan, 2008; Kurniawan, 2006). Though, the literature research revealed several games having similar purposes for computer devices only. These applications have been excluded. Furthermore, the search was limited to articles that are available to the general public. Another limitation represents the focus on cognitive functions exclusively, although psychological functions can come along with AD and other Dementias as well. Future research should concentrate in deep for the specific success each application can demonstrate referring to the underlying cognitive stimuli addressed. It needs to be further investigated which stimuli might have more success than others to provide an indicator for an early AD or Dementia. These insights will lead to better working solutions for this purpose.
Furthermore, these results could be further investigated by adding psychological functions in the analysis criteria to find out, whether cognitive or psychological stimuli suit best for this purpose. Another future research stream is to take a closer look on the various applications identified in this research in terms of their entertaining and fun aspects that they provide for the users. Within qualitative studies, it can be evaluated which applications are the favorite ones for the target group of elderly people.

Conclusion

Since there is a research gap for mobile applications designed for elderly people which offer serious games or playful elements aiming to detect an early cognitive decline, this paper begins to reduce this lack. This research revealed that the use of serious games and other mobile applications with playful elements on mobile devices offers great opportunities in geriatrics research. However, there are only few efforts to apply them for detection purposes referring to the assessment of cognitive health. In the existing literature, only six applications could be identified. None of them is already able to provide robust detection mechanisms of

cognitive decline. It turned out that the cognitive stimuli "memory" is addressed most in the existing applications as a potential indicator for AD and Dementia. The applications need further scientific evaluation in terms of reliability and validity. Still, initial results promise opportunities for the future. This review is intended to provide the basis for further researches in this area.

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