Serious Games for Dementia

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ABSTRACT
With the current phenomenon of aging populations in most parts of the world, there are corresponding increases in age-related conditions associated with impaired cognitive status, such as dementia and delirium. Cognitive status is a key component in carrying out activities of daily living such as walking and bathing, and departures from normal cognitive status may be indicators of acute (e.g., delirium) or chronic (e.g., dementia) conditions. Individuals with cognitive impairments may benefit from playing serious games, which are games designed for a primary purpose other than entertainment. Serious games can potentially assess a variety of factors associated with cognitive decline in dementia, while keeping individuals active and stimulated, thereby potentially slowing down or furthering cognitive decline. In this workshop paper, we discuss the development and use of serious games focusing on cognitive functions that are affected by the progression of dementia.

Categories and Subject Descriptors
D.2.10 Design: Human Factors

General Terms
Design, Human Factors

Keywords
Activities of daily living; Alzheimer's disease; cognitive assessments; cognitive screening; dementia; executive function; games; gamification; human factors; instrumental activities of daily living; serious games.

1. INTRODUCTION
The rapid aging in many societies is leading to an increasing prevalence of age-related conditions associated with abnormal cognitive status, such as delirium, and dementia [1]. Other aging-related issues that affect quality of life, and the ability to live independently, include frailty and loss of functional status. In Canada alone, 20% of people over the age of 65 are estimated to be frail [22]. Cognitive impairment is an important component of the cumulative deficits that contribute to frailty, and cognitive abilities such as memory and executive functioning are necessary for performing activities of daily living.

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According to the Alzheimer's Association (2015), 32% of Americans aged 85 or older have Alzheimer's Dementia (AD), and AD is currently the sixth leading cause of death in the United States. There appear to be a number of risk factors for AD, including family members with dementia [13], traumatic brain injury [14], mid-life obesity and diabetes [3], and depression [6].

Since cognition is a highly complex construct that involves many different types of abilities, we will describe a serious game that provides a general assessment of executive function (a unified approach), as well as being potentially applicable to a range of disorders related to aging. We will also propose development of specialized serious games that can be targeted to other more specialized components of cognition (a fractionated approach). To demonstrate this fractionated approach, we consider specific examples of serious games that assess functions that are expected to decline as people progress through the dementia lifecycle.

In the following discussion, we begin by discussing a serious game for individuals with cognitive impairment that we have developed. This "Executive Timed Target Game" (a version of the whack-a-mole game) assesses inhibition ability, which is related to overall executive functioning ability [17]. Inhibition ability declines with age in older adults [23]. Reduced executive function abilities, as people age, adversely impact functional abilities required in completing activities of daily living (ADLs) such as bathing and walking [10]. Thus in developing the game we hypothesized that performance on the game should be related to a number of clinical assessments, not only of cognitive status, but also of other measures related to executive functioning, such as ADLs.

2. EXECUTIVE TIMED TARGET GAME
Our serious game mimics features of the classic psychological Go/No-Go Discrimination Task [33], a measure of inhibition ability. As implemented, our game is similar to the carnival game "whack-a-mole" (see Figure 1). In a previous study with healthy younger adults we found that our serious game had a significant relationship ($r = 0.60$, $p < 0.01$, one-tailed), with the Stroop task [28]. The Stroop task is a test of the inhibitory executive function, which declines with age, and which has been shown to correlate with white matter loss in the brain (e.g., [20]).

We evaluated our Executive Timed Target Game with a sample of elderly emergency patients [29], and compared response time (RT) performance on the serious game to scores on standard cognitive assessment methods such as the Mini Mental State Examination (MMSE) [9] and Montreal Cognitive Assessment (MoCA) [18]. Median game RT was significantly correlated with both the MMSE (r =-0.558, $p < 0.001$), and MoCA (r =-0.339, $p < 0.001$) in elderly emergency department (ED) patients and differences were in the expected direction (slower game RT for people with possible mild cognitive impairment assessed using the

MoCA, and for people with dementia as assessed using the MMSE). In our study, we observed a correlation of $r = 0.630$ ($p < 0.001$) between the MMSE and MoCA scores. This compares fairly well with the correlations of $r = 0.430$ between the MMSE and MoCA scores for healthy controls and $r = 0.600$ for patients with mild cognitive impairment found previously [30]. Overall, the correlation of our serious game with existing methods of clinical cognitive assessment appears to be almost as strong as the correlations of the clinical assessment methods with themselves. The correlations between the global mental status tests observed in this study are similar to results seen in other research.

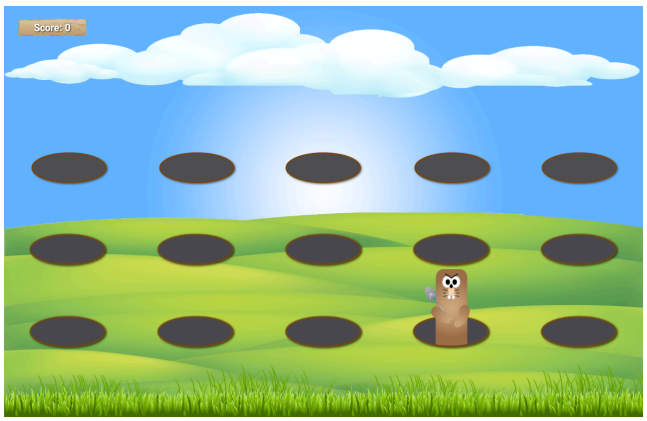

Figure 1: Screen capture of the Executive Timed Target Game.

We examined the relationship between serious game performance and MMSE scores, using a cutoff where an MMSE score of less than 24 was indicative of possible dementia [9,19]. Using a serious game median RT cutoff of 1.1 seconds, (approximately the same as a 1.13 second value used for delirium screening we had identified in previous research [29]) we obtained a specificity of 86% (86/99) and sensitivity of 76% (13/17) (see **Table 1**) [29]. Thus, using a common MMSE cutoff value, we were able to identify 13 out of 17 patients with dementia as identified using the MMSE.

Table 1: Predicted versus actual MMSE scores using a serious game RT cutoff of 1.1 seconds [29]**.**

		Actual MMSE Score	
		MMSE >= 24	MMSE < 24
Predicted MMSE Score	MMSE >= 24	86	4
	MMSE < 24	13	13

In addition to the Executive Timed Target Task being able to screen for signs of cognitive impairment by examining overall executive function of inhibition, it is also an enjoyable and usable game for patients at risk of or with cognitive impairments. In our study with older ED patients [29], we received comments on the game from research assistant who helped carry out the study with patients:

- "Loved the game, she was playing games on her iPhone before I approached her"
- "Enjoyed the game, he would play on his own,"
- "Really loved the tablet, wanted to keep playing even after testing was over."

Overall, this case study demonstrates the feasibility of using serious games for cognitive assessment of older adults in clinical settings.

3. A MULTIPLICITY OF SERIOUS GAMES FOR DEMENTIA

In the preceding section, we showed how one serious game that assesses the overall executive function of inhibition can be predictive of a number of different clinical assessment tools, can also be enjoyable for older adults to play in a clinical context. In this section, we consider alternative types of game that might be relevant to the assessment of particular cognitive functions within people with dementia.

3.1 Previous Research

There are existing games that have either been designed for patients with dementia or have been used in research studies with dementia patients. Work by [16] suggests that serious games for dementia can be broken down into three primary areas which are: cognitive, physical and social/emotional. A variety of games for dementia are available on different mediums including computers [26], mobile devices [15], and gaming consoles such as the Nintendo Wii [4,8,11,21,27].

The computer game, SmartBrain Games, is a collection of online cognitive training games designed for adults of all ages. This software was evaluated by [26], which compared the efficacy of using this software while participating in an integrated psycho-stimulated program (IPP), to a group receiving only the IPP, and another group receiving cholinesterase inhibitors. Their findings suggest that patients in groups that played the game and received IPP, demonstrated higher cognition than those that only received IPP. Moreover, other form factors such as mobile devices have been explored as a medium for playing games by dementia patients. Research by [15] demonstrated that a majority of their sample with mild dementia were able to play the MasterQuiz game independently on a tablet device.

A Nintendo Wii game (Wii Sports) has been explored by [11] to assess this system's usability by AD patients and performance improvements were observed. Other researchers have also studied the entertainment and physical value of Wii Sports, and demonstrated that dementia patients found this suite of games enjoyable [27] and observed improvements in game scores in the bowling game [8]. In addition, [21] demonstrated that AD patients that played the Nintendo WiiFit, experienced significant improvements in their gait and balance compared to the control group who participated in a walking program.

Another Nintendo Wii game called MINWii, which is a music therapy game designed for AD and dementia patients, was investigated by [4]. This research demonstrated that patients were able to use a virtual keyboard to interact with the game. The researchers noted that this game encouraged meaningful interactions between patients and their caregivers. Overall, research using the Wii has demonstrated that dementia and AD patients may benefit from playing games on the Wii system for their physical and emotional health.

3.2 Proposed Approach

While executive functioning is an important component of cognitive status, it is not the only component. In this section, we consider the challenge of designing games for dementia using a

fractionated approach. Dementia is a multi-faceted disease that tends to manifest different symptoms as it progresses. In the following discussion, we will focus on loss of cognitive function within AD, where the disease typically evolves within an individual in a relatively predictable progression. According to [5], dementia progresses from the entorhinal cortex to the dentate gyrus and the hippocampus generally and then on through other parts of the brain. One reason for this progression may be some kind of pathogenic protein spread of neuro-degeneration (see [31] for a critical review of this hypothesis). If the staging of dementia by brain locations were characterized in detail, then it should be possible to trace the progression of AD by degradation in performance of a succession of cognitive tests that target the different parts of the brain corresponding to the different stages of AD progression. In the meantime, however, it is still possible to enumerate critical abilities that are targeted by dementia as it progresses, regardless of the order of that progression, and to design detailed cognitive assessments for each of those abilities [5].

In the approach recommended here, we propose designing serious games for dementia that target different cognitive abilities. For instance, some of the key cognitive functions lost as dementia progresses include:

- Short-term memory (acquisition of new information)
- Long-term memory (retention of old information)
- Switching (the ability to switch quickly and easily between different tasks)
- Word or object recognition
- Time and place orientation

Serious games can be developed to target each of these functions (see Figure 2). The advantage of this approach is that individuals with dementia with different cognitive abilities can enjoy games. In addition, these serious games can also help create a profile across different components of cognitive status relatively easily in non-clinical settings (e.g., long-term care). For example, a cognitive impaired adult experiencing difficult with a task switching game may be experiencing loss in this cognitive domain and can potentially benefit from playing games that focus on this ability.

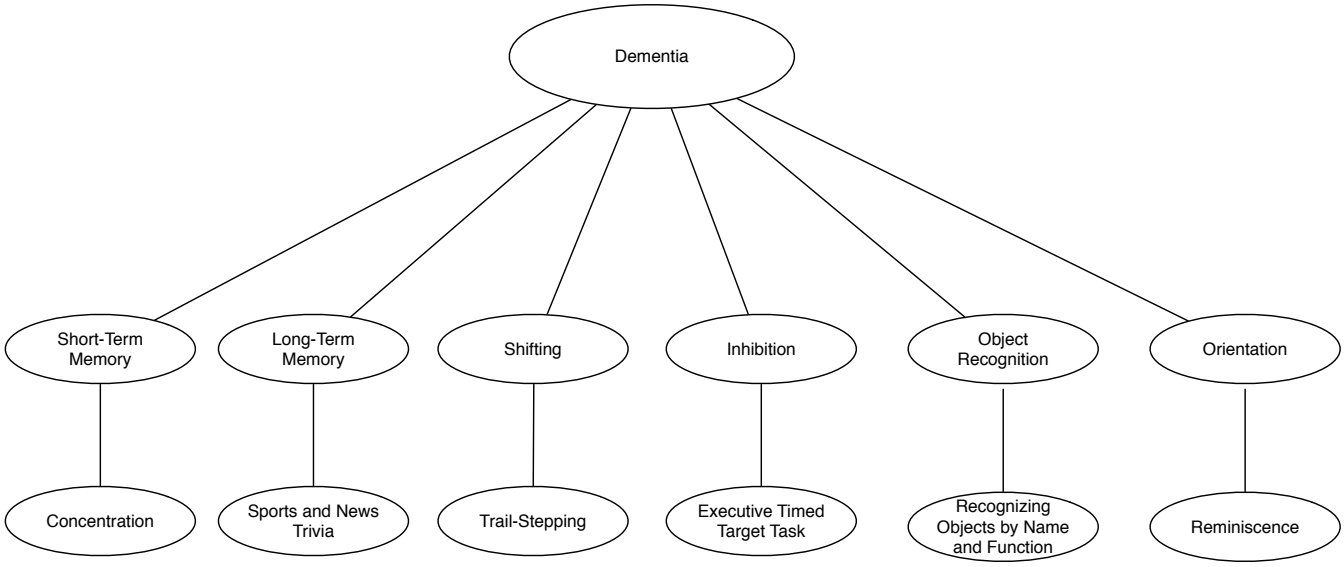

Figure 2: Roadmap of serious games for cognitive screening in AD dementia.

Figure 2 shows some initial mappings between possible games that can be used by people living with dementia and corresponding cognitive components affected by dementia. For short-term memory, the focus is on the acquisition of new information. This can be over a short period of time (e.g., remembering where matching card pairs are in the Concentration memory card game) or for a longer period (e.g., remembering a new person's name). In **Figure 2**, we have included Concentration, as it is an existing game that people like to play and it assesses short-term memory. For longer-term storage of new material, one might develop a game where the player meets new people and has to remember their names.

Trivia Games, such as Trivial Pursuit, are tests of long-term memory. Their validity depends on the relevance of the content to the person being tested. For instance, a sports trivia game will not be a good form of long-term memory assessment if the person had no interest in sports when they were younger. Thus a trivia game would first need to test for a person's interests and then focus on content that was meaningful to that person. For executive functioning, we recommend the use of the Executive Timed Target Game because it has been shown to be related to overall executive function (inhibition) and, as noted above, it is correlated with existing measures of delirium, dementia, and frailty.

Ideally, an enjoyable existing game could be selected that was a relatively pure measure of each cognitive component of interest. In practice, this may be hard to do. For a function like object recognition, assessment should probably involve recognizing objects by name and function. However, this type of recognition task does not seem intrinsically enjoyable and thus it may be difficult to get people to play it repeatedly unless some kind of reward is provided for playing the game. Gamification (e.g., [25]) is a strategy for making tasks more game-like. Leaderboards and badges have been found to motivate young people to carry out gamified tasks (e.g., [7]). However, older people, and people with

dementia in particular, represent a more challenging population (e.g., [15]) and games will need to be crafted carefully, not only to match physical and cognitive abilities, but also to match interests.

Part B of the Trail-Making Test [12] is a shifting/switching task where the person has to trace out two sequences of numbers and letters in an alternating fashion (A-1-B-2…etc.). An example of a recent game that implements shifting using a trail making approach is Trail-Stepping [24], which is a step-version of the Trail-Making Test, based on the game Dance, Dance Revolution, that trains visual attention and set-shifting. The game requires participants to step on mat panels to connect numbers, or numbers and letters, in alternating order as fast as possible. A representation of the mat is projected on to a screen in front of the participant and circles with numbers and/or letters appear in random order on the panels onto which the participant steps. A red line (trail) is then drawn between circles when correct steps were made, thus providing feedback. [24] tested Trail-Stepping with community-living adults. While it worked well in that context, it seems likely that the game is too complex for people with dementia. However, Trail-Stepping shows how shifting functions can be assessed using a serious game, and it, or something similar, might be useful in tracking possible progressions from mild cognitive impairment to dementia.

The final cognitive component considered here is orientation. Loss of orientation may involve losing track of what day it is, but may also include loss of sense of self and failures in autobiographical memory, which tend to be more prevalent for people with dementia [2]. Reminiscence therapy has been developed as a way to strengthen sense of self and improve communication although strong research results in support of the method are not yet available [32]. Reminiscence games can provide people with photos, videos, and other clippings from their life so that they can tell part of their life story to other people, or else re-experience their own memories.

4. CONCLUSIONS

In this paper, we focused on serious games for individuals with dementia. Since our focus was on games that are enjoyable but somewhat challenging it is possible that they may potentially be useful for brain fitness exercise, but a consideration of such usage is outside the scope of this paper.

This paper outlines two major types of serious game for dementia. A game like the Executive Timed Target Game assesses a very generalized cognitive ability (executive functioning) and consequently we have found it to be potentially useful in cognitive screening for a variety of conditions (delirium and, dementia, while also being related to cognitive aspects of frailty and to ADLs). A second type of game then focuses on more specific cognitive abilities. For instance, Trail-Stepper assesses shifting ability. Further research is needed to develop a taxonomy of cognitive abilities affected by conditions such as dementia, and to develop fractionated serious games targeted to each of the specific cognitive abilities in that the taxonomy.

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