



AN INNOVATIVE MOBILE GAME FOR DETECTING COGNITIVE CHANGES

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INTRODUCTION

This paper presents a mobile game for smartphones and tablets, developed to detect the frequency and extent of memory slips. Memory slips are a natural phenomenon associated with cognitive changes as one ages. Although everyone will experience memory slips or more colloquially “senior moments”, not everyone who experiences memory slips will develop dementia. However, memory slips however can be symptomatic of more serious cognitive decline and the onset of dementias.

In this work, we present an innovative means to quantitatively assess and monitor memory slips through a non-invasive mobile game.

BACKGROUND AND OTHER METHODS

A. Background

Currently, over 35 million people are living with dementia and that number is expected to reach 115 million by 2050 fueled by an aging population (WHO, 2012). The negative impacts of diagnoses on the individual and their family and caregivers are significant, and research implies that early diagnosis can assist in introducing therapies that can slow the progression and maintain quality of life for longer (Prince et al., 2011).

This work is part of the field exploring the role that mobile devices may play within the niche of mobile apps related to mental health maintenance, assessment and promotion, and specific to the elderly or aging. Mental health apps fall under a much larger space of mobile health apps (mHealth apps) which focus on the practice of medicine and public health mediated by mobile devices. This work falls into the development of mobile health apps specific to mental health assessment in aging, the process

of learning and memory slip, and a technology for empirical assessment. To constrain the scope, this work is contextualized within mobile gaming with the goal of learning a strategy and tracking player performance. Within general health and lifestyle apps, the area of collecting mental health data from Smartphones is very promising (Luxton, 2011, Torous et al., 2014). Many apps typically address self-monitoring and self-management of mental health concerns such as depression, anxiety, stress, and their associated manifestations. Smartphones offer advantages over other means of mental health technologies (Proudfoot, 2013), such as being very inexpensive, easy to deploy and from which to collect data. While there is little empirical clinical data supporting the efficacy of mental health apps (Donker et al., 2013), the science is still in its infancy (Athens, 2016) and the landscape points to the need for further evidence-based research (Donker et al., 2013; Hollis et al., 2015). Smartphones may have the potential to be effective in many mental health scenarios (Donker et al., 2013), and while there is research and development activity in this area, few are specifically oriented to aging, Alzheimer’s disease and other dementias, or measuring and analysing memory slip (Landhuis, 2015). There are other tests for pre-symptomatic Alzheimer’s, but currently it is unclear if one test is better—and more likely, several will be used to assess the disease’s progression (Landhuis, 2015). The research will supplement available tools via long-term game-interaction data collection and its correlation to pre-symptomatic cognitive decline.

B. Other Methods

Alzheimer’s Disease does not affect all memory capacities equally: short-term memory (the ability of hold information in mind in an active, readily-available state for a short period

of time) is the first to go. Next, episodic memory (memory of autobiographical events) is compromised, followed by semantic memory (memory of the meanings of words and facts about the world). Finally, procedural memory (how to perform tasks and skills) is lost. As the disease advances, parts of memory which were previously intact also become impaired (http://www.human-memory.net/disorders_alzheimers.html).

Others methods that aim to monitor memory slip and cognitive decline tend to be more deterministic than the techniques described here. For example, for a test at brainhealthregistry.org a person is presented with a series of photos and is asked if they have seen the photo for a second time. This type of instrument addresses short-term memory and does not provide a means for other than binary and deterministic outcomes. Most current screening applications are of this type. On the other end of the test spectrum are eye tracking technologies, premised on the idea that eyes will track in a greater range and/or at greater speeds when someone is trying to identify an unfamiliar object (i.e. when one believes that one is seeing it for the first time, or is trying to 'place' the image) rather than when one observes a known, familiar object. These are not currently scalable within a Smartphone technology, but also lack any procedural memory component.

OUR APPROACH

This project represents one of the first, if not the first, mobile app for purposes of assessment and analysis correlated to memory slips and other age-related cognitive processes, as a means to detect pre-symptomatic cognitive decline. The significance of the research is that, the software framework can be made available to others researchers and to other users, creating a crowdsourced database of game data across multiple age ranges. With a fully functional prototype completed, researchers will be in a very unique position to gain greater insight into player behaviours (cognitive processes) alongside more traditional Smartphone or dementia screening methods.

Previous work within the research group has led to a prototype software platform (mobile

game) capable of collecting simple user data. Currently, this framework consists of a prototype online two-player card game, similar to the easy-to-play and familiar card game War (denoted MOBRO WAR). A screenshot is illustrated in Fig.1. A single game consists of five rounds, each game played is measured in seconds, and feedback is near instantaneous. Each player knows their own cards and can play them in any order during the round, playing against the app (a 'bot'). In its current form, the 'bot' plays the same strategy for 100 rounds, either low-to-high, high-to-low, or middle-high-low, and it is incumbent upon the player to recognize the 'bot's' strategy and counter appropriately. At each round, the probability of winning by chance vs. winning by learned strategy are recalculated, and the player's score is evaluated accordingly.

Further work will focus on developing this prototype into a robust and reliable software platform capable of collecting data related to player performance useful to assessing strategy learning and retention. The collected data will include duration of play, speed of each round, number of games played, and player choices in each card hand. The data will be collected to determine differences between older and younger players as well as between various other groups.



Fig. 1: Example play of MOBRO WAR

There are several design factors that support the conjecture that this instrument can contribute to quantitatively assessing memory loss:

- Our mobile app uses engages short term, episodic, semantic as well as procedural memory. That is, our app requires both recall as well as thinking/analyzing in determining

or learning a strategy as well as recalling strategy.

- Since the game is played repeatedly in short burst, a person can learn a strategy and, in the absence of cognitive decline or memory slip, will tend to reinforce their strategy with an increasing score differential.
- Since the game involves a degree of randomness, it is possible to play the learned strategy, i.e. the winning strategy (on average) but still lose a round or hand. This ability to still lose (in spite of playing the “winning” strategy that a person has learned) can bring on a moment of confusion and trigger a memory slip.
- Each round is played with random cards which also can induce a moment of rethinking that can bring about a memory slip. These latter points are somewhat speculative but worth further research.

In effect, the randomness of the cards and the probabilistic event of losing the hand even though the “winning” strategy was played both have an impact. These features make this mobile game different from others which tend to be more deterministic.

To accommodate players who would find a five-card hand too difficult (for example, due to a higher degree of cognitive decline), the game can easily be redeveloped with only three cards, thereby reducing the apparent degree of difficulty while retaining the stochastic nature of play. This stochastic nature of the game is core and essential to its novelty and originality in potentially triggering and monitoring a memory slip.

Proposed data analysis procedures: At present, there is very little research on real-time data collection within mental health games. This work represents the first effort to capture player behavioral patterns with emphasis on better understanding memory slips, widely recognized in the literature as a potentially major step in assisting in assessing cognitive degeneration.

What follows are some theorized examples of how the collected data may be used to better understand the analytic potential.

Understanding demography: Collected data could be used to explore the demographic profile of participants in the game/s. We anticipate that analysis by age, sex, region (potentially taken by proxy measures of IP addresses) could be performed. However, there are ethical and data confidentiality issues to be addressed, and it is uncertain whether this could be achieved in practice and beyond the scope of the present paper.

Understanding different types and patterns of play: We anticipate that sub-group analysis will be possible. Having complete control over the platform, it will be possible to gain objective data about frequency of play, length of sessions and player choices in each card hand, which would be informative in describing and contrasting different types of participants.

Understanding trajectories: If an on-going relationship can be established with a group of participants, a system can be set up to explore the behavior and the play of select individuals longitudinally, examining changes in their play strategies and scores over time. It could also accommodate examination of behaviours of groups over time, including those who play consistently at certain levels, those who increase their involvement with these games, those who display variable patterns of play and those who stop play. Once these trajectories are identified, their profile may be explored.

Most importantly, the player’s user data allows us to assess their probability of maintaining a winning strategy throughout play. As a person encounters difficulty with recall, the probability of winning is reduced until the participant recalls or relearns their winning strategy.

Table 1 illustrates some preliminary results from a simple user trial illustrating some of the data currently collected by the mobile game, illustrating a person’s ability to beat a bot by more than chance (statistically significant).

For development iterations, we control installations of the mobile game on to users’ smartphones by hosting the game app ourselves on a secure server and inviting volunteers and the research team to “side load” the game. This allows considerable control over the game during development and debugging.

TABLE 1: PLAYER RECORDS (PROTOTYPE TEST VOLUNTEERS)

User	Level 1		Level 2		Level 3		Level 4	
	win	loss	win	loss	win	loss	Win	loss
Bob	142	53	220	74	292	101		
Ken	70	30						
Kevin	85	12	160	34	219	50		
Mehrdad	80	16					317	72
Sridhar	69	28	208	87				
Farnaz	80	19	162	35	256	51		
Rahul	75	26						
Fernando	76	23	149	50	213	83		

One would be remiss not to mention the opportunities for integrating machine learning (ML) into mental health Smartphone apps. For example, Song and Diederich (2014) discuss the use of N-gram concept features and Support Vector Machines (SVMs) for predicting Speech and Language Disorder assessment items automatically from speech samples. While not aligned directly with mental health assessment, there are clearly opportunities related to speech capture on a Smartphone that would be amenable to ML classification. Similarly, there are Smartphone opportunities for mental health assessment through ML and face image classification (Wang et al., 2015).

SUMMARY

This paper presented a novel means of assessing memory slips, associating them with cognitive decline. The statistical method tracks a person's ability to learn and retain a winning strategy in a mobile game over time. If a memory slip is detected or a player's pattern of play varies significantly, it may be as a result of a memory slip in comparison to their more normal play.

Upon acceptance, the mobile game (app) will be demonstrated at the conference, including the opportunity for others to play several rounds. Perhaps somewhat serendipitously, one may experience a memory slip while playing.

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