Connecting the player to the doctor: utilising serious games for cognitive training & screening

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ABSTRACT
In this paper, we discuss the limitations of common cognitive training and cognitive screening methods, and examine how serious games could address some of these issues. We propose a cognitive game system, supporting self-care of cognitive health, in non-clinical settings, which can also function as a connection between the players/patients and their mental health clinician.

Author Keywords
Cognitive screening; cognitive training; dementia; self-care; serious games.

ACM Classification Keywords
H.5.m. Information Interfaces & Presentation: Miscellaneous

INTRODUCTION
Older adults often present symptoms of associated memory impairment, both for declarative and episodic memories. These symptoms can be caused by normal aging processes, but also indicate the potential development of Alzheimer's disease (AD) - the most common form of dementia [16]. Although current Alzheimer's treatments cannot stop Alzheimer's from progressing, they can temporarily slow the worsening of dementia symptoms and improve quality of life for those with Alzheimer's and their caregivers. Today, there is a worldwide effort to find better ways to treat the disease, delay its onset, and prevent it from developing [9].

Dementia is a devastating disease for the patient, their carers, and family. The cost of dementia care is also starting to have a significant impact on the healthcare systems of many countries [12]. Despite the increasing costs, and potentially because of the cost of front line care, there are limited resources available to support research into early detection and monitoring of pre-clinical patients. As a result of this, the cognitive assessment for the progression of cognitive impairments is mostly based on the passage of time rather than the cognitive performance of the patient over a specific period of time, making it difficult to track the point in time when the cognitive decline begins to takes place. Consequently, doctors treating dementia do not have the right kind of data at the right time in order to be able to help the patient most effectively. This situation, mostly affects the patients at preclinical stages and those of Mild Cognitive Impairment (MCI), which

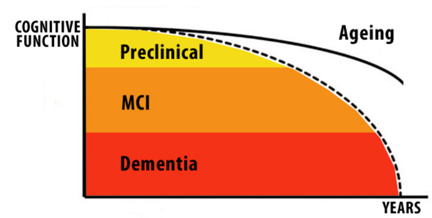

Figure 1. The continuum of normal ageing and Alzheimer's cognitive decline [19].

is considered to be the transition phase between healthy ageing and dementia [14] (Fig. 1). The progression from MCI to dementia appears to be time dependent - occurring primarily within the initial 18 months [3] - and the doctor could treat the patient more effectively with access to timely monitoring, since initiating treatment early may have significant and clinically meaningful advantages in the course of the dementia disease, for example in early clinical trials with donepezil shows potential to delay the onset of Alzheimer's dementia [8]. *Cognitive training* has shown promise as a preventative treatment in the premorbid stage. Clinicians encourage older adults to engage in self-care for cognitive health, through everyday cognitively stimulating activities in non-clinical settings (e.g. patients' homes, senior centres et al.) [21]. Another preventative approach is the identification of patient's cognitive status by *cognitive screening* in clinical settings (i.e. hospitals, memory clinics etc.).

In this work, we discuss cognitive training and cognitive screening, focusing on current limitations, and propose a cognitive game system, utilising Augmented Reality (AR), to address those problems. Through the proposed system, we are planning to further examine our research hypothesis that the introduction of Augmented Reality gaming can benefit the cognitive training and screening processes, being a tool for self-care of cognitive health and connecting the player to the doctor when that is necessary. In the context of this study, self-care of cognitive health takes the form of an active process of engaging individuals to take responsibility for managing aspects of their mental health and adopting behaviours that prevent cognitive decline. Through active participation in their health management, patients are empowered to have more control over their daily lives by purposely engaging in cognitively stimulating activities, self-monitoring and implementing a course of actions in a timely manner (e.g. visiting the mental health clinician) that can lessen or slow down the debilitating symptoms of cognitive decline [4].

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COGNITIVE SCREENING: TESTS & LIMITATIONS

Cognitive impairment is measured objectively by standard neuropsychological (cognitive) tests. Cognitive screening represents the initial step in a process of further assessment for dementia and can help identify potential cases for assessment, thus leading to early diagnosis. Early diagnosis provides the opportunity for cognitive training and pharmacological management, if appropriate, with the hope of preserving or improving executive function, behaviour, and cognition [11]. Screening for dementia is usually accomplished by means of cognitive tests. The most widely-used are the Mini-Mental State Exam (MMSE) [5] for screening severe dementia and the Montreal Cognitive Assessment (MoCA) [15] for screening Mild Cognitive Impairment (MCI).

However, these screening tests present certain intrinsic limitations [11]. MMSE contains *culture, gender, and educational bias*. Additionally, patients with high premorbid intelligence or education show a ceiling effect, thus leading to false negatives. Great age, limited education, foreign culture, and sensory impairment can conversely produce false positives. Therefore, the MMSE score is adjusted for age and education [11]. Demographic based adjustments are common for the majority of cognitive tests, however the MoCA test is increasing in usage, as it appears to have less bias related to cultural and educational elements [11].

Almost all screening tests, as longitudinal and mostly static (pen and paper) measures of screening, they are susceptible to the *learning effect* and are considered to be *psychologically stressful*, presenting a risk of false positive results with concomitant distress and potential stigma for a person labelled with cognitive impairment. Furthermore, most of these tests *target specific stages of cognitive impairment*, not providing an objective overview of the patient's cognitive status (e.g. MMSE cannot be used to identify MCI). Finally, one needs to consider the capacity of local health care services given the *economic burden of increased screening* [11].

COGNITIVE TRAINING: GAMES & LIMITATIONS

Examination of the range and limits of cognitive reserve capacity (plasticity) by means of cognitive training has been suggested as a promising diagnostic strategy for the early identification of dementia, particularly Alzheimer's disease, in sub-clinical populations [6]. Furthermore, cognitive training aims to help people with early-stage dementia delay the disease's onset and make the most of their memory and cognitive functioning despite the difficulties they are experiencing, by utilising compensatory and/or restorative strategies [1]. Cognitive training shows promise in the treatment of AD, with primarily medium effect sizes for learning, memory, executive functioning, activities of daily living, general cognitive problems, depression, and self-rated general functioning [17], the retrospective and observational designs of the human studies have led to difficulty interpreting the direction of causation between cognitive function and cognitively stimulating activities [13]. To face the new challenges that arise from an ageing society, serious games are presented as a cognitive training platform to slow the cognitive decline of impaired patients.

Figure 2. Using AR cube/markers to manipulate in-game elements.

Cognitive training games present several problems and have their own limitations. Current cognitive training games *focus mainly and directly on the serious aspects*, i.e. the stimulation of the targeted cognitive functions, at the expense of the game design. Consequently, a large number of cognitive training games are *low-quality games*, not utilising the appropriate game design and game mechanics and fail to either engage or entertain the player.

From an interaction point of view, most of the cognitive training games presented in [13] suffer from multiple important limitations since they *do not fulfil perceptual and interaction needs of cognitively impaired patients* [2]. These games are designed exclusively as entertainment or wellbeing games, with a "typical user" in mind [10], which have acquired serious games characteristics through studies that test their efficacy on a group of patients. These games may be suitable for cognitively impaired patients, but are not specifically designed and targeted for them. As a consequence, many of the current serious games for dementia do not take into consideration the fragile cognitive state of the player, thus adding extra cognitive (and possibly physical) load through complicated and non-customisable interaction techniques, complex and non-adaptive game scenarios, and cognitively dense artistic design [2].

A significant limitation that runs through most of the current cognitive training games is that there is still *a gap between non-clinical and clinical settings*, that does not allow those games to act as accredited screening and self-monitoring tools for the early identification of cognitive decline, and to connect with formal care, such as medical experts. The value to the medical profession is limited by the lack of data collection and analysis related to cognitive function and status. Game performance indicators such as game score often bear little relationship to general cognitive competence.

A PROPOSED COGNITIVE GAME SYSTEM

The main idea that runs through this work is that cognitive games (i.e. games for cognitive training and screening) can potentially be a tool for self-care of cognitive health, providing cognitive exercise and self-monitoring. The proposed cognitive game system is the study object of the GameLab in Gjøvik University College and its functionality covers the preclinical and early MCI stages of cognitive impairment (Fig. 1), where the users can have subjective memory complaints, however present normal performance of activities of daily living (ADL) and normal general cognitive function, and where there is no need for formal and/or informal care.

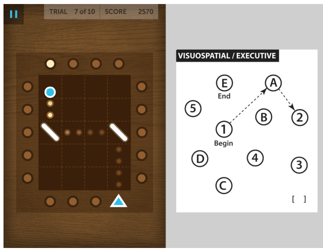

Figure 3. The Pinball Recall Lumosity game for cognitive training of working memory (*left*) and a visuospatial/executive "find the logical path" exercise from the MoCA screening test (*right*).

Architecture

The architecture of the system consists of a wearable and mobile system, based on the use of AR and on manipulating the in-game elements using hand movements. More specifically, the system consists of a pair of AR glasses and a number of AR markers (Fig. 2) for "building" the AR scene and manipulating the in-game objects. We focus on AR glasses (Google, Glass, Meta Spaceglasses et al.), since glasses are an accepted way of altering our perception of the world.

Interaction

Recent advances in technology (e.g. gestures/hand tracking, Augmented Reality, biosensors, high-fidelity Virtual Reality et al.) allow us to have several new interaction methods at our disposal. New interaction techniques can *reduce the cognitive load of in-game instructions*, *stimulate and register the physical abilities of the players*, and *provide the developer and the formal care with secondary data*. In our study, we utilise the Augmented Reality technology in order to overcome the interaction problems, related to traditional interaction techniques [2, 10] and we hypothesise that AR can be utilised to implement a cognitively-suitable interaction technique for elderly players. AR has been shown to provide a pleasant cognitive training experience for elderly players, because of its simplicity and usability of the interface, as described in the Eldergames project (presented as a mixed-reality platform) [7]. Furthermore, AR systems improve task performance and can relieve mental workload on assembly tasks. The ability to overlay and register information on the interaction space in a spatially meaningful way allows AR to be a more effective instructional medium. However, the limitations in the current calibration techniques, display and tracking technologies (e.g. the occlusion of AR markers issue) are the biggest obstacles preventing AR from being a wide-spread medium [20]. As designers, we are planning to make use of the performance gains of AR and address its problematic areas, by implementing an interaction technique for elderly players, which is based on assembling in-game elements by moving AR markers (such as AR cubes - Fig. 2) with hand movements, attempting to provide a pleasant cognitive training experience and stimulate the motor skills of the players as well. Furthermore, the collection of untrained secondary data, facilitated by the proposed interaction technique (e.g. hand movements coordinates, revealing hand tremors), provides extra data for clinical evaluation, which is potentially less effected by the learning effect of the games [18].

Content

Cognitive screening tests and cognitive training exercises have game-like elements or, at least, elements that can be gamified (e.g. Fig. 3). That alone allows us, as game designers, to *implement game scenarios where cognitive training exercises coexist with the cognitive screening ones*, developing a healthcare instrument of dual nature. The content of the proposed game is based on a set of puzzle mini-games, targeting the visuospatial, memory, attention, problem solving and logical reasoning cognitive functions amongst others. The functionality and the cognitive-related content of the games, as well as the proper interaction movements (focusing on motor skills) will be decided by the team's neuropsychologist. As examples of best practices concepts of popular and entertaining puzzle and platform games (e.g. Wooord, Threes, 2048, DragonBox), as well as gamified versions of cognitive tests' exercises, will be examined for integration and implementation purposes. *Cognitive games' content can also be dynamic*, as opposed to the static/paper version of the widely-used cognitive screening tests, thus eliminating the learning effect. In the proposed game, several levels of the mini-games will be dynamically generated and new levels will be added frequently as expansion packs or downloadable content. The dynamically generated content will be based on a validated and pre-approved set of rules for level generation, where the content will be changing but its essence and functionality will remain the same.

Intrinsic objective

A cognitive game can give the player an informal measurement of his/her cognitive performance through the game score. Taking as a prerequisite that the proposed game's content consists of accredited cognitive exercises (i.e. the mini-games), *the correlation of the game score with the cognitive status of the player* (as screened by the "gold standard" methods - the MoCA test in our case) could provide the player/patient a constant monitoring of his/her mental health. The vision of the project is a system where gaming is used as a motivational and engaging way of cognitive self-monitoring and, if indications of cognitive decline appear, the player will be notified by an in-game message to reach out for formal care and treatment. If the player is an already enrolled cognitively impaired patient, the doctor will have the opportunity to follow his/her performance, get notified of sudden cognitive changes, get supplementary secondary data (e.g. hand movements coordinates), as well as, choose the set of games that are suitable for the player's cognitive status and set the game score/performance thresholds. Consequently, the constant cognitive monitoring and screening of the player can provide the opportunity for formal care to assess the progression of cognitive impairments based on the cognitive performance of the patient and provide treatment only when necessary, *thus reducing the financial burden on the social welfare system.*

CONCLUSION

Current cognitive training and screening methods, even being of great scientific and health value, present certain limitations.

	Limitations	Cognitive games' solutions
Cognitive screening	culture, gender, and educational bias	dynamically generated, updated content
	learning effect	dynamically generated, updated content
	psychologically stressful	entertaining game experience
	target specific stages of cognitive impairment	various sets of exercises/games
	economic burden of screening/automated screening	fewer and more targeted medical examinations
Cognitive training	low-quality game design, too "serious" - less fun	entertainment is an important target, inclusion of game professionals
	no perceptual/interaction needs of CI patients	examination/use of current interaction technologies/techniques
	no link between non-clinical and clinical settings	correlation of game score and real cognitive status, connecting player to the doctor

Table 1. A summary of the cognitive screening and training limitations and how cognitive games can address them.

With the current advances in technology we hypothesise that an optimised version of the two processes can be introduced as a tool for self-care of cognitive health: cognitive games. Cognitive games can be studied not only as a mean to surpass those limitations (Table 1), but to motivate the player in order to provide himself/herself and the system with objective cognitive data. If this data is interpreted and handled correctly, they potentially can reveal the cognitive changes of the player, connecting him/her with the formal care in a cognitive-timely manner. Even though, such a project is of a long-term nature, we consider that its promising character is worth further discussion and examination.

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