Mobile 'SqueeView': Caring for the elderly with Mobile Learning

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ABSTRACT
As we are encountering to the aging society, the interest of serious games gets increasing. In this respect,'*SqueeView*' is aimed at enhancing visuo-spatial cognition of the elderly. In an empirical study with 35 mature adults, it was revealed that *SqueeView* had a significant effect for improving their visuo-spatial cognition capability. However, the SqueeView game that is based on the desktop computing environment is limited on time and space. We further address this issue with a new design concept on a mobile platform that can integrate game-based learning contents and computerized cognitive assessment.

AUTHOR KEYWORDS
Serious game, SqueeView, mobile learning, rehabilitation, cognitive assessment

INTRODUCTION
As the elderly are positioned themselves as the critical mass of the society's demographical structure, a lot of medical technologies in conjunction with new ICT (Information and Communication Technology) have been proposed (e.g., brain fitness program). Even mobile-based cognitive assessment has been introduced, such as CANTAB™ Mobile that detects the earliest signs of dementia. By this more effective and simple interventions can be made to prolong the patient's independence.

Indeed, the assessment-based application holds a strong position in effective patient identification and stratification to help target treatments more efficiently, but it would not be of great value for the elderly to enjoy optimal cognitive health and wellbeing throughout life. In this regard, serious games have been attractive, such as exertainment, that adds an entertainment factor to the well-known fitness programmes (e.g., Nintendo Wii Fit™ or Microsoft Xbox Your Shape™ Fitness Evolve). In conjunction with enhancing motor skills, rehabilitation program also focuses on boosting up their cognitive capability, and motivates the elderly to positively engage in it (Cameirão *et al.*, 2009).

However, most of the serious games now in the commercial market are accustomed to the desktop computing environment. It is partly due to technological limitations on the processing speed, display resolution, and a lack of input modalities. This makes people who use serious games much limited to time and space. At present, users should play games indoor such as rest homes, hospitals or rehabilitation centres, and occasionally need assistants to help them to perform those games correctly.

Perhaps, one of the main reasons why the game-based rehabilitation programmes are not quick to reach to the elderly or patients would be that they cannot assess the changes of their cognitive capability. Hence, relevant experts such as doctors or therapists are necessary to the adoption of the technology. On the other hand, the advent of mobile devices can make cross above and beyond the borders of the traditional gaming environment, with the help of their portability and constant accessibility, allowing users to access various facilities such as other smart devices or web pages while they are on the move. Moreover, they can provide information adapted to user's contexts such as time and space, and allow people to access information more efficiently and directly (Goodman *et al.*, 2004). Thus, combining these advantages of mobile technologies to serious games will make a synergy effect, but it is still elusive how to make this happen.

With this umbrella scope of the research goal, we take a first step to suggest a novel serious game for the elderly. In this article, we first present a brief overview of serious games in the rehabilitation area. Next introduces a new serious game called '*SqueeView*', which has been designed for prevention of dementia and its benefits for cognitive rehabilitation is demonstrated with an empirical study. Based on the findings, we finally propose a new design concept, and how mobile learning can be inserted into the arena of the serious game.

SERIOUS GAMES IN PREVENTION AND REHABILITATION
Several serious games for a clinical purpose have recently been highlighted as a new way of rehabilitation. These game-based rehabilitations reach widely a variety of user groups from children to the elderly who are suffering from impaired physical or cognitive abilities. At the same time, serious games for rehabilitation become specific for a target cognitive or physical treatment (or both).

The benefits of serious games have been measured and validated through their therapeutic successes in different application areas, for instance, stroke (Ma *et al.*,2008), diabetes (Brown *et al.*, 1997) and asthma (Lieberman, 2001). By comparison, serious games for cognitive rehabilitation (e.g., HERMES Maze and HERMES Waterfalls) are now of much interest in order to assist executive processing, visual attention and visual-manual coordination (Buiza *et al.*, 2009).

Indeed, some studies demonstrated that cognitive rehabilitation can be in parallel with physical exercises. For instance, Cameirão *et al.* (2009) have shown that the stroke patients had enhanced their cognitive and motor ability at the same time using a VR-based serious game.

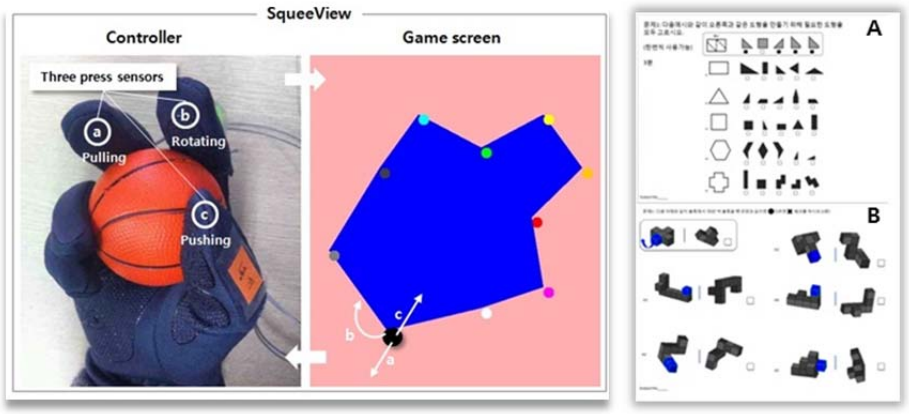
Game	Platform	Application area	Reference
Otago Exercises	Computer	Motor	Doyle *et al.*, (2010)
ArrowAttack	Computer	Motor	Burke *et al.*, (2009)
Cybercyle	Computer	Cognitive	Anderson-Hanley *et al.*, (2012)
TheraGame	Computer	Cognitive and Motor	Kizony *et al.*, (2006)
Silver Balance	Computer	Cognitive and Motor	Gerling *et al.*, (2010)
Sphere chasing task	Computer	Cognitive and Motor	Cameirão *et al.*, (2009)
HERMES Maze, Waterfalls	Interactive Table	Cognitive	Buiza*et al.*, (2009)
Bowling	Mobile	Motor	Sunwoo *et al.*, (2010)
Penguin Toss	Mobile	Motor	Sunwoo *et al.*, (2010)

Table 1. Serious games for rehabilitation for the elderly (not exhaustive)

Table 1 lists some serious games for either physical or cognitive rehabilitation or both, for the elderly. Many of them have been developed based on a desktop computer platform, rather than a portable one. It is partly because recent serious games require high performance devices using sensing technologies (e.g., depth camera). In spite of a great evolution of mobile technologies, including processor speed, storage capability, sensing technologies, display resolution, it is still quite away from the adoption of mobile platform for playing serious games. Indeed, the serious games for rehabilitation are often very expensive, heavy and take up too much places to be installed at home. Therefore, most serious games for rehabilitation have been deployed in such as rehabilitation centres, rest homes, and hospitals. However, considering that most age-related illness in the elderly often needs a long-term treatment, the accessibility and personalisation is key to development, by which it means that the mobile platform would be of great value.

SQUEEVIEW: AN EMPIRICAL STUDY

That said, we developed a first prototype called '*SqueeView*'. It is mainly designed to prevent or treat the dementia for the elderly, by improving their cognitive ability (especially, spatial skills such as spatial visualisation and mental rotation) along with several finger motor skill exercises (Heyn *et al.*, 2004). An empirical test of this prototype was firstly performed, its mobile version (tentatively called, '*SqueeView Mobile*') is now being developed. *SqueeView Mobile* will provide portability and accessibility to overcome the limitations of the first prototype. Indeed, the glove type of input device in *SqueeView* is not useable for the mobile platform, a new input system like Synaptics Fuse (http://www.synaptics.com/demos/fuse) is now thus being developed.



(a) (b)

Figure 1. (a) Schematic of '*SqueeView*'; (b) two types of cognitive test (A: Form Board Test VZ-1; B: 3D mental rotation test)

System Overview

'*SqueeView*' is inspired by the baby's finger movements, similar to squeezing a ball enhancing dementia patients' cognitive capability (Scherder *et al.*, 2008). To play '*Squeeview*', a patient wears a glove, which integrates the three press sensors on the tips of the fingers (see Figure 1(a)). Each sensor detects separate finger actions: rotating for the index finger, pushing for the thumb, pulling for the middle finger, as shown in Figure 1(a). Using an ordinary elastic ball, the patient can naturally grasp it and manipulate each finger as she/he plays a real-time *SqueeView* game on the computer screen. *SqueeView* game comprises a series of geometric polygons. Each game needs to make a given polygon by using the three fingers, i.e., pulling (middle finger), pushing (thumb), or rotating (index finger) (Choi *et al*., 2012).

Participants/Apparatus/Procedure/Design

An experiment was designed to see the gaming effects of *SqueeView*. Thirty-five participants (avg.= 50.17 yrs.); twenty-three were male. They were later randomly assigned into either the treatment condition (i.e., *SqueeView*, n=25) or the active control condition (i.e., Tangram, n=10). Tangram is widely used for improving visuo-spatial skills (i.e. spatial visualization and mental rotation; Linn and Petersen, 1985) in the clinic. The assessment of cognitive capability was

made by the two types of cognitive tests: *Form Board Test VZ-1*(Ekstrom *et al.*, 1976) and *3D mental rotation test* (Shepard and Metzler, 1971), as shown in Figure 1(b). A total duration of the experiment was 30 minutes (Step 1: Pre-test (5 mins.); Step 2: Main experiment (15 mins.); Step 3: Post-test (10 mins.)).

Results and Discussion

The mean scores of the cognitive assessment tests are shown in Table 1. In the *SqueeView* group, they were significantly increased from pre-test to post-test in Test A (t_{24}=-3.46, p<.05). However, it was not the case for Test B (3D mental rotation test). This result partially indicates that *SqueeView* could present some advantages over the traditional cognitive games (here, tangram). In particular, the current version of *Squeeview*, which provides two-dimensional game tasks, seems to be effective to separately enhance 2D visuo-spatial visualisation skills rather than three-dimensional mental rotation skills. Indeed, the results imply that jointly training cognitive and motor skills might be more successful for enhancing cognitive ability compared to a single cognitive training (i.e., Tangram). However, a careful interpretation of the results is separately needed, in that the 3D mental rotation test (i.e., Test B) did not reveal the benefits of *SqueeView*, which is planned to further examine in the near future.

	***SqueeView* (n=25)**				**Tangram (n=10)**			
Test types	Pre-test score	Post-test score	Change	*p*-value	Pre-test score	Post-test score	Change	*p*-value
Test A (max=5, min=-5)	-0.84	0.96	1.80	0.002*	0.6	1.9	1.30	0.10
Test B (max=5, min=-5)	3.08	3.48	0.40	0.32	4.2	4.2	0.00	1.00

Table 2. A comparison of progress in cognitive performances, * significance at 0.05 level

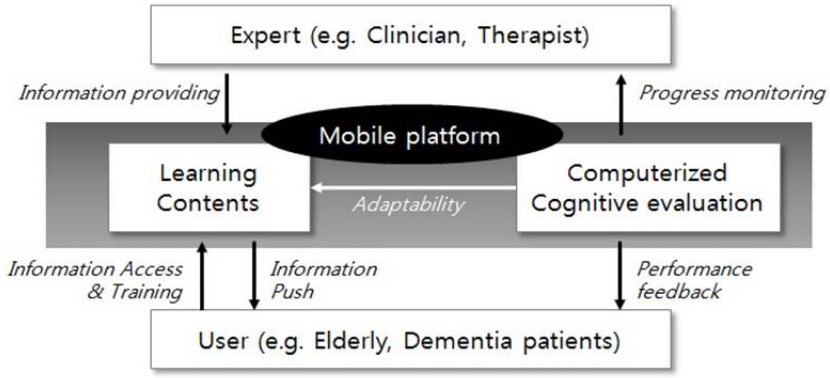


Figure 2. A new design framework of serious games for rehabilitation on a mobile platform

SQUEEVIEW MOBILE – INTEGRATING SQUEEVIEW WITH MOBILE LEARNING

That being partially identified the benefits of both '*SqueeView*' and its cognitive assessment tests, it can be more effective by being portable because a long-term training of dementia or cognitively impaired patients is essential (Volicer *et al.*, 2006). We are now sketching out '*SqueeView Mobile*' from two perspectives. First, as a series of cognitive assessment test are recently computerised as shown in such as Raven's test (Raven, 2000), '*SqueeView Mobile*' is also needed to present an instant feedback of their performance to further motivate the players. Secondly, not simply playing the mobile serious game, '*SqueeView Mobile*' can provide appropriate learning contents (e.g., dietary information, new exercise programs) under the mobile learning paradigm.

The main benefits of 'SqueeView Mobile' would be *easy access to information* and *adaptive learning contents*. First, through the middle layer of a mobile-based rehabilitation programme (as shown in Figure 2), clinical and training information can be effectively transferred across experts and actual user groups (mostly, the elderly). The learning contents include both game-based learning contents and non-clinical information, such as nutrition, dietary information, lifestyle consulting, and clinical schedules. Second, the notion of 'adaptability' of learning contents on a mobile platform is also applicable. As mentioned in the previous section, there are several types of cognitive assessments, which is often available only in the hospital or rehabilitation centre. Thus, a mobile-based rehabilitation programme is necessary to integrate both learning contents and cognitive assessment tools, so that they are quick to suggest best-possible game-based training and information. In addition, experts (e.g., clinicians, therapists) can monitor the progress of patient's cognitive or physical performance and adjust later her/his rehabilitation programme, if necessary.

We are currently updating *SqueeView* based on the proposed design framework above. In order to design a mobile '*SqueeView*', a similar prototype is now being made, like Synaptics 'Fuse™'(http://www.synaptics.com/demos/fuse). Also, a series of cognitive assessment sets have been computerized, that can be found at http://hci.hanyang.ac.kr/Experiment.html.

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