The Design and Study of a Serious Game for Attention Training of the Older Adults

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Abstract. In this research, we have designed a parameterizable serious game on tablet computer to study how such a system can improve the attention of the older adults. In the experiments, we have adopted two types of tests: Visual Search (VS) and Attention Network Test (ANT) as the pretests and posttests. In the game sessions, we have incorporated visual search exercises in the game to provide attention trainings for the older adults. The experimental results show that some cognitive abilities of the participants can be significantly improved, and most of the subjects are willing to continue to play the game after the experiments. The design of our serious game succeeded in achieving the goal of attention training for the older adults.

Keywords: game-based learning, cognitive abilities, parameterization, older adults, attention

1. Introduction

Many countries are facing the problem of becoming an aging society. The percentage of older adults with declined cognitive abilities is increasing. The goal of our system is to design a serious game to improve the attention of the older adults. Due to the declined cognitive abilities of the older adults, it is crucial to design a game that can not only increase their motivation but also serve the purpose of attention training. As revealed in the study of Slegers[8], compared to the younger generations, the older adults have a stronger preference of games over other computer application software (such as word processing, email, and web browsers). Therefore, in this work, we aim to design a game-based learning system for the older adults to perform attention training. In order to lower the barrier of playing a game for the older adults, we have taken advantage of the intuitive user interface provided by a tablet computer to design our serious game. We conduct experiments to study how this kind of serious game can slow down the deterioration or even improve the attention of the older adults.

The main contribution of this work is the development of a novel serious game that features parameterizable design settings and incorporation of psychological tests in the game contents. We have also conducted experiments to demonstrate that such a game-based learning system can effectively improve the attention of the older adults.

2. Related Work

There have been many research efforts invested on the development of simulation games for military training. The Dismounted Soldier Training System is one of the examples. In 2007, Marks [6] evaluated these games from the aspects of editing, content, and gameplay and designed a game for several popular game engines to test their performance in these three aspects. In this work, we have chosen the Unity 3D game engine by the Unity Technologies as our platform for its features of cross-platform and portability to mobile devices. According to Siriarya [7], the older adults are more likely to feel anxious with 3D games due to the unfamiliarity of interactions in a 3D environment. Therefore, in our system, we have chosen to design a 2D game on a tablet computer to avoid complex scenes and interactions.

There have been many researches concerning the changes of cognitive abilities through training. For example, Berry [1] has pointed out that through the training of programming, the functions of working memory of the participants can be improved. Through an affective speech interface, mental disorder can also be effectively improved [5]. Fan et al. [3] combined three types of networks: alerting, orienting, and executive attentions to form the Attention Network Test (ANT), which is also the test that we have adopted for the measurements of attentions in pretest and posttest.

Some researchers have investigated how older adults perceive 3C products (such as personal computer, smart phone and tablet computer) by means of surveys. However, we have not seen much work on incorporating psychological tests to develop games for learning. Caste [2] had conducted a study that used commercial games to train selective attention. However, in order to reduce the effort for designing a new game stage and prevent the users from losing interests on playing the same content repeatedly, it is desirable to have a game that is not only designed specifically for attention training but also be customizable by parameter settings, which is also the design goal of this work.

3. System Design

Most of the commercialized games in the market nowadays target the young or the adults. There are very few games or interface designed specifically for the older adults. Considering the psychological and physiological status of the elderly, the interface design of the game system should be adjusted accordingly. For example, in the user interface, we do not only enlarge all fonts used in all stages, but also have a tips button in game to remind the participants their objectives. In addition, the game system is also designed with appropriate sound effects to strengthen the objectives of the story in each stage. The complexity of the operations demanded in playing game as well as the visual complexity of the interface should also be reduced.

In addition to the consideration of complexity, our game system also includes the following features. First, **t**he proposed system creates game stages on the fly through an external xml file describing tests in a stage, game scenes and other settings. From a user-specified folder, it loads settings such as object type, model name, position, rotation, scale, and other additional script files and creates a game accordingly. In addition, all images or training contents can also be customized through external files. For visual search, the variations of object features such color, shape, size, and status (static/dynamic) can be specified to create variety of games for attention training. Furthermore, our system records all activities in a game session and export the data for further exploration. The recorded data include stage code, stage module, answer, reaction time and object names (target, non-target and distractor).

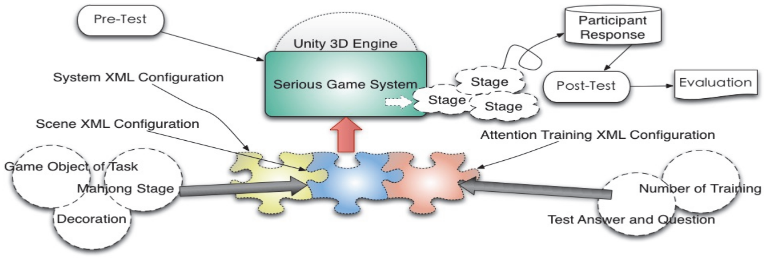

Fig. 1. system architecture of our serious game

3.1. System Architecture

The design goal of the game system is to provide a game environment with an intuitive interface and flexible content parameterization for attention training. In order to provide an intuitive interface for the older adults, we aim to design the game for a tablet computer, which has been shown to be more friendly for older adults. The architecture of the system is shown in Fig. 1. Besides the pretests and posttests, the core of game system consists of three components that take inputs of system settings, scene settings and attention training settings. According to these settings, the game system generate a variety of game stages automatically on Unity 3D. The scene settings are the specification of game stages such as stories, dialogues, decorations and triggers. The settings for attention training control the training contexts including training type, number of training objects and object positions in a scene. The process and performance of a user in a game session are recorded for future analysis. With these settings, our system can generate new game stages on the fly without changing the code while providing rich game contents for strengthening training effect. In other words, the users of our game system who have learned markup language (xml) before could create a new game stage easily and quickly by modifying the settings and resources such as stage background image, target-item(image), non-target item, distractor item, story scenario (including text and audio file) and related resources.

3.2. Game Flow

In each stage of our game, a user goes through several steps. The game starts with an introduction screen and a menu for selecting game scenarios. Once a game scenario is selected, the story for the scenario is presented to the user. We have designed the story scenarios to be as common in the daily life of an older adult as possible in order to quickly engage the participants. The system describes the objective of the game and what the participants should focus on during the game. In each stage of the game, the participants are asked to achieve the game objective while obtaining their attention training repeatedly. Each participant is asked to try four different levels (easy, normal, hard, and challenging) of attention training in each stage with six rounds in each level. As depicted in Fig 2, in each round, there are 15 object items of three types (target, non-target, and distractor) on the screen. The participants are asked to touch the target object under the distraction of the distractor objects which look salient and different from the target object. The target object remains the same in a game scenario while the non-target objects become more and more similar to the target object when the game level become higher. When a game is finished, the participants enter a score page showing their scores, times, and ranks for providing feedback of achievement and motivation for further game playing.

Fig. 2. Snapshot of the story mode in a game stage

4. Experimental Results

All the participants recruited were randomly assigned to the experimental or control groups with the proportion of about 3:1. The data collected were compared between these two groups to reveal the effects of training with our serious game. Twenty three participants were willing to attend this experiment to have 5-day training. Five of them were male. The range of their age was 69-92, with the mean of 83. Short Portable Mental Status Questionnaire (SPMSQ) was adopted as the screening test for excluding the participants with dementia. None of the participants was excluded.

At the beginning, we have 17 participants in experimental group and 6 participants in control group. But two of the participants in the control group did not complete the experiment. As a result, we have only 4 participants in the control group in the end. Therefore, the data collected from the control group is shown in descriptive statistics for reference only and did not apply a statistical test to compare with that of the experimental group.

4.1. Experimental Design

The whole experiment lasted for three and four weeks for the control group and experimental group, respectively. In the first week, all of the participants were given the pretests (including VS and ANT) individually. In the second week, participants in the experimental group were asked to use the game system for 30 minutes each day for 5 consecutive days. In each day, the training took place from 3pm to 5pm regularly. Participants took the training in batches with 7-9 participants in a batch. The participants in the control group were given other activities using the same device. In the third week, all the participants were given the posttests (also including VS and ANT) individually. Finally, in the fourth week, participants in the experimental group were given a questionnaire asking some questions about the experience or opinions regarding this game system.

The procedure of the whole experiment is as follows: (1) SPMSQ: a screening test to exclude the participants having dementia. (2) Pretest: including 80 trials of the VS task and 96 trials of the ANT task. (3) Training: 30-minute attention training with serious game each day using a tablet computer for the experimental group; 30-minute jigsaw puzzle playing each day using a tablet computer for the control group. (4) Posttest: the same as the pretest. (5) Questionnaire: asking the participants in experimental group some questions about this experiment and game system.

4.2. Experimental Results

4.2.1. Visual Search

In the visual search task, distractors were present or absent with equal probability. The mean accuracy of the 2(distractor: present, absent)×2(test: pretest, posttest) conditions from the experimental group is shown in Table 1. From the data, we can find that performance of the participants in the posttest is improved compared to the pretest. A two-way ANOVA with repeated-measures applying to this data shows a significant main effect of the test (pretest *vs.* posttest), $F(1,16)=11.398$, $MSe=0.293$, $p< .01$. The interaction of distractor and test is not significant. This means that performance improved in the posttest irrespective of the presence or absence of the distractors.

Table 1. Mean accuracy of visual search in pretest and posttest of experimental group.

distractor	pretest	posttest
present	0.38 (0.13)	0.51 (0.11)
absent	0.40 (0.14)	0.52 (0.08)

Note: The value inside the parentheses is standard deviation (SD) of that condition. Accuracy is scored in probability (0-1).

As for the reaction time, variability of the data is rather large. There were large differences even among the participants with the similar age. Although there were also small improvements in the posttest compared to the pretest, the difference between them does not reach significant level statistically. Therefore, the major improvement is shown in accuracy rather than reaction time.

The accuracy data from the control group is shown in Table 2. There are similar trend as found in the experimental group. But the difference cannot be evidenced by statistical test.

Table 2. Mean accuracy of visual search in pretest and posttest of control group.

distractor	pretest		posttest	
present	0.41	(0.11)	0.58	(0.01)
absent	0.47	(0.05)	0.54	(0.12)

Note: The value inside the parentheses is SD. Accuracy is scored in probability (0-1).

Based on the results of the visual search task discussed above, participants in the experimental group improved their attention in the accuracy data. The training effect of our game system is supported in this respect.

Table 3: Mean scores of various measures in ANT of experimental group.

	pretest		posttest	
Alerting	-0.06	(0.19)	0.04	(0.14)
Orienting	-0.07	(0.17)	0.01	(0.15)
Executive	0.11	(0.17)	0.28	(0.43)
Reaction time	1.82	(0.61)	1.58	(0.44)
Accuracy	0.86	(0.18)	0.98	(0.03)

Note: The value inside the parentheses is SD. Reaction time is measured in seconds. Accuracy is scored in probability.

4.2.2.Attention Network Test

Scores of alerting effect, orienting effect and executive control effect are calculated based on the work of Fan et al. [5]. Table 3 shows the mean score of each measure in the pretest and posttest from the experimental group. Mean reaction time and mean accuracy are also included. In these measures, alerting scores reflect the efficiency of achieving and maintaining an alert state. Orienting scores reflect the efficiency of selecting information from sensory input. Scores of executive control reflect the efficiency of resolving conflict among responses.

For comparing the scores of pretest and posttest in experimental group, a matched-sample t test was applied to each measure separately. The results show that the differences between pretest and posttest in alerting score and orienting score are significant, $t(16)=-1.72$, $p=.05$; $t(16)=-1.70$, $p=.05$. In addition, the differences in reaction time and accuracy are also significant, $t(16)=2.44$, $p=.01$; $t(16)=-2.81$, $p=.01$.

Table 4 shows the data from the control group. We found that the mean scores did not differ much between pretest and posttest in most of the measures. Especially, it is worthy to note that alerting score and orienting score improved significantly from the pretest to the posttest in experimental group. However, the same improvement cannot be found in the control group. Overall, the results in ANT show that attention training with our game system can improve the efficiency of alerting network and orienting network. But the effect on executive control network cannot be evidenced.

Table 4: Mean scores of various measures in ANT of control group.

	pretest		posttest	
Alerting	-0.13	(0.09)	-0.13	(0.23)
Orienting	-0.19	(0.30)	-0.10	(0.17)
Executive	0.19	(0.10)	-0.06	(0.35)
Reaction time	2.03	(0.64)	1.71	(0.85)
Accuracy	0.84	(0.27)	0.87	(0.23)

Note: The value inside the parentheses is SD. Reaction time is measured in seconds. Accuracy is scored in probability.

The improvement of performance in ANT after training is also reflected in the reaction time and accuracy for the experimental group as shown above. This result differs from the result of VS in which the reaction time did not improve after training. It may be due to the high difficulty of VS for the older adults as shown in low accuracy and long reaction time, so that attention training with our game system cannot improve both the accuracy and reaction time in VS.

4.2.3.Analysis of the data in the game process

The data recorded in the process of 5-day training with our game system was analyzed. Among the 17 participants, ten of them improved their reaction time for the color task day by day gradually. Seven participants improved their performance for the color task or shape task abruptly in the second day, and then maintain the same level or improved slowly for the rest of days. In one of the participants, the reaction time for the shape task slowed down gradually.

Furthermore, we divide the participants into the light-using group (n=8) and heavy-using group (n=9) based on their total frequency of game-playing in five days. Mean frequency of using in light-using group is 416, with the range of 251-504. Mean frequency of using in heavy-using group is 712, with the range of 507-1179. In the light-using group, only 4 of the 8 participants improved their performance obviously. In contrast, all of the 9 participants in the heavy-using group improved their performance obviously. This result supports the effect of attention training with our game system further.

In order to understand the relationship between frequency of using and the improvement in the attention task (such as ANT), the Pearson product-moment correlation coefficient (r) is calculated. The results show that frequency of using correlated significantly with accuracy in ANT, $r = .551$, $t(15) = 2.55$, $p < .05$ (one-tailed). This result echoes the training effect observed in accuracy data discussed above.

5. Conclusions and Future Work

Based on the results of the experiment in this research, playing a serious game incorporating the concept of attention training from cognitive psychology can successfully improve attention in the older adults. Among the three scores in ANT, our game system has effects mostly on the alerting network and orienting network. It means that the older adults can achieve or maintain an alerting state more easily after training. Also they can shift their attention to the critical location with the aid of cue in the environment. All these are important for the older adults in everyday life.

Another contribution of our work is the parameterization in the designing of game for attention training. With parameterization, the adaptability of our game system is increased, and the design cost is reduced. In addition, recording data during the process of game-playing for exploring the learning effect in depth is also available in this approach. Furthermore, we have got mostly positive feedbacks from the participants, demonstrating the effectiveness of our system in engaging the elders in playing the game while getting trainings.

In the future, the degree of customization and parameterization in system design can be augmented further. Presently, the elements under our control include game stage, background story, image, and the test content. In the future, an authoring interface may be designed to provide a more intuitive interaction for creating game stages and test contents. Even more, adjusting the sound effects and particle effects directly through a parameter file is expected to be realized in the new design.

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