Designing Brain Training Games and Evaluating the Usability between Young and Elderly

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***Abstract*—There is few researches focus on investigating game player's experience and preference between the young and elderly. In this study, four different braining training games designed by us are used to investigate the effects of age and game preference. In total, 136 participants were randomly selected, and they are separated into two age groups- young (N=90) and old (N=46). The experimental results demonstrate differential age effects in braining training games performance. Our results show that no matter what types of games young adults get better performance than the older adults and they all reach a significant difference. Meanwhile, due to the interface design may affect the willingness of older adults to play the game. Therefore, the usability is also studied by the design of game's control keys in a car racing game. The experimental results show that, older people respond relatively more slowly than the young people. Therefore, simpler interface design of brain training game is more suitable for older adults. In addition, the survey results indicated that the fruit catching game is loved by most of old people (reached 41.2%). The main reasons are without problem-solving stress and easy to play- player only need to control the right and left arrow keys. In other words, no psychological burden and simple interface design are the key factors in design popular games for elderly. However, young group is more like car racing game than others (28.6%). Since it is a playable game and they get a feeling of satisfaction when they reach a lower lap time. Finally, the brain age reference diagrams for the four developed games are proposed. Players can use these diagrams to understand their capability with respect to young and old group.**

Keywords-brain training game; usability; brain age

I. INTRODUCTION

There is great potential for computer games developed for the amusement of young adults to produce cognitive benefits in older adults [1]. Meanwhile, the growing market of seniors and retirees offers great opportunities for business growth and development. Therefore, many commercial games for braining training are developed specifically for seniors in United States and Japan. For examples, brain training games developed by CogniFit [2], Posit Science [3], Happyneuron [4], Fit Brains [5], Lumosity [6] and Japanese Nintendo DS (Brain Age 2), play in PC, web page or mobile devices

Reimers and Maylor [7] used an internet-based task-switching experiment to investigate age-related changes in executive control with 5,271 participants between the ages of 10 and 66 years. The experimental results demonstrate differential age effects in task-switching performance. Zelinski and Reyes [1] developed a basis for the hypothesis that digital action games may produce cognitive benefits for older adults. Their results showed that the specific cognitive abilities proposed to be improved by different types of game genres are outlined, and recent developments in game and interface design that may affect the willingness of older adults to play are described. Amanda et al [8] reviewed the existing research literature on digital games played by older adults to assess whether playing digital game improves health outcomes of elderly. Their results showed that there was a significant positive effect on health outcomes associated with digital game play among older adults.

Nacke et al [9] investigate effects of age and game form on usability, self-assessment, and play experience in an arithmetic challenges. Their results showed that players, regardless of age, are more effective and efficient using pen-and-paper than using a Nintendo DS console. Meanwhile, no significant interaction effects between age and game form were found. They did not find any significant interaction effects between age and game form. In this paper, the effects of age and game types on usability are studied. However, the gap between the commercial game and the academic research on senior's game is still large, especially in the art and elegant aspects. Therefore, the questionnaire survey results about usability and playing experience may not reflect the actual circumstances. In this study, we will try to promote the game's art and elegant aspects by our department students in art and design to reduce above gap.

II. RESEARCH METHODOLOGY

In Wiki's definition, usability is the ease of use and learnability of a human-made object. It also refers to how satisfied users are with that process. In software engineering, usability is about effectiveness, efficiency and the overall satisfaction of the user [10]. In general, usability evaluation mainly focuses on how well users can learn and use a product to achieve their goals. A common measure of effectiveness is the number of errors made by the user while

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attempting to accomplish a task or task completion time [11] [12]. This study employs four braining training games developed by us, to investigate effects of age, game form and control interface design on usability. Each game will play several times, after removing the highest and lowest points, the middle three scores are taken average as the performance of the player. If the data is incomplete or score deviation is too large, they will be discarded (not included in the calculation of the amount of statistics).

A. Research participants

In the original we have 152 participants. But we want to provide a brain age reference diagram, based on the playing data of participants. In order to increase the representation of statistical data, we divide all participants their age into several groups and limit the number of each group is at least 6. Therefore, the youth data is divided into four age groups (18, 19, 20 and 21). Meanwhile, the elderly data is divided into four age groups (55-60, 60-65, 65-70 and above 70). The rest of the data, 16 participants, were discarded from the analysis.

Finally in total, 136 participants were randomly selected, and they are separated into two age groups- young and old. In the elderly group, 46 individuals aged between 55 and 78 years were selected as participants (20 males and 26 females) and have a mean age of 63.9 years. Meanwhile, all elderly participants were screened for mental and physical well-being. 14 participants (30%) stated that they had played a digital game before. The distribution of educational status in elderly is elementary school (43.5%), junior high school (34.8%), high school (13.0%) and college (8.7%). For the younger comparison group, 90 university students aged between 18 and 21 years in department of multimedia and game science in Taiwan were selected. All of them are often played digital games. The young group consisted of 56 (62.2%) male and 34 (37.8%) female individuals.

B. Game design and implementation

In this study, two types of games- training for response speed and training for problem solving, are developed by us. Due to many brain training games provide variety problem solving (math) games for elderly, therefore we design a giving change game and a game for four fundamental operations of arithmetic to investigate the player's experience and preference between game forms. In addition, in order to study the design of game's interface two different games are developed for response speed. The first one is a more complex control interface game using 4 arrows keys to play, named as car racing game. The second one is an easy control interface game only using left and right arrow keys to play, name as fruit catching game. All four games are implemented by Microsoft XNA 4.0 game development platform. The XNA platform is a programming environment that allows users to create games for Windows Phone, the Xbox 360 console, and Windows based computers.

C. The Car Racing Game

To evaluate whether an interactive system is easy and pleasant to use, a typical car racing game is developed to evaluate the usability, as depicted in Fig. 1. In the beginning, the car moving forward with a constant speed. In playing, players can navigate the car to turn left or right by using the keyboard's left and right arrow keys. Meanwhile, players can use up and down arrow keys to speed up and slow down the car. Another two cars controlled by game AI of way points are used as NPC (Non-Player Character) to provide guidance to players. When the car completes the entire circle, the lap time will be recorded.

Figure 1. Car racing game

D. Fruit Catching Game

To verify the proposed method, a fruit catching game is selected as the training of response speed, as shown in Fig. 2. This game is a simple and easy game, users only need to control the left and right arrow keys to move the character and catch all the fruit before they fall on the ground. The game time is set to 60 seconds. Meanwhile, player will get 1 point, when they catch a falling item.

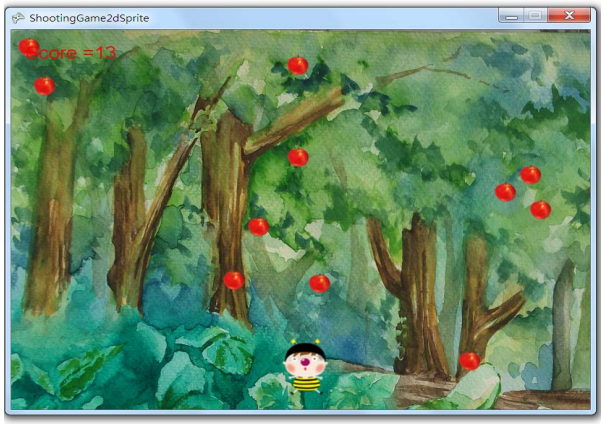

Figure 2. Fruit catching game

E. *Giving change game*

Purchasing everyday items is an important thing for older adults in daily life. In this study, a giving change game is developed and designed by us as a type of game on problem solving. The game will random generate the shopping price between 1 to 999 NT dollars, and auto decision given user a NT1000 or NT500 to pay the above purchase price. The player need to drag the right amount of coins and bills (NT) to the answer space to give back correct change. In addition, the right answer requires to use the least amount of coins and bills. For older adults, this game may sharpen their mind, improve their focus, and review their knowledge of coins and bills in no time. The game time is set to 3 minutes. When players finish the game, players will see the accuracy, by ratio of correct answers to total number of questions.

F. *Game for the four fundamental operations of arithmetic*

In here, another type of basic mathematics game that will help elderly recall and sharpen their basic mathematics skills is developed and designed by us, as shown in Fig. 3. In this game, players will give two small numbers between 1 to 10 and a target number. Player need to make the number sentences true using the given numbers and any of the four operations- addition, subtraction, multiplication and division, so that the result will reach the target number. The game time is set to 60 seconds. Meanwhile, the number of correct answers will show in screen, when the game time is up.

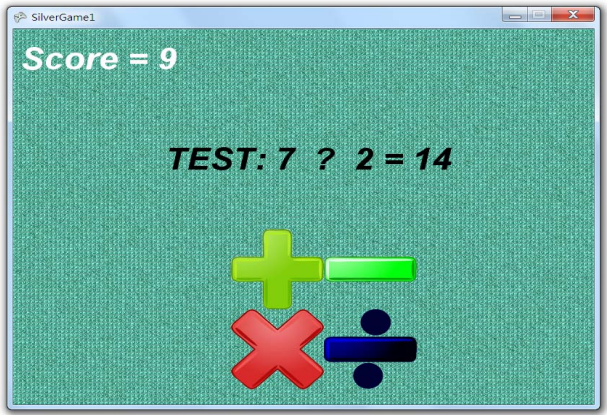

Figure 3. Game for the four fundamental operations of arithmetic

III. EXPERIMENTAL RESULTS

A. *Usability measure and the design of control interface for response speed training*

In this study, there are two different games are developed for response speed, a car racing game and a fruit catching game. In the car racing game, 4 arrows keys are used to control the car and the usability is measured by the car's lap time. In order to understand whether there is a significant difference between the young and elderly in response speed using in our developed car racing game. The independent samples T-test is used here to analyze the difference between the young (N=90) and elderly (N=46). The results are shown in Table 1. From Table 1, the difference between the young and elderly reach a statistical significance level (t= -13.015, p=.000 < 0.05). It means the response time of young in playing a car racing game is more fast than elderly.

TABLE I. ANALYSIS OF USABILITY IN A CAR RACING AND FRUIT CATCHING GAME

Response speed	Group	No	Mean	Standard deviation	t	Sig.
Car game (lap time)	Young	90	66.61	8.327	-13.02	.000*
	Elderly	46	100.83	22.123		
Catching game (#catching)	Young	90	51.27	7.310	24.865	.000*
	Elderly	46	19.65	6.392		

Meanwhile, a fruit catching game using only left and right arrows keys to control the player character is developed as a simple game for training response speed. The usability of this game is measured by the number of catching items (fruit) in one minute. The independent samples T-test results are also shown in Table 1. The results indicate that young adults have more fast response in catching items than the older adults (t = 24.865, p=.000<0.05). So response ability of young adults in playing game is significantly better than older adults.

TABLE II. ANALYSIS OF THE CONTROL INTERFACE IN A CAR RACING GAME

Car game	Group	No	Mean	Standard deviation	t	Sig.
Up key	Young	90	8.82	.978	40.318	.000*
	Elderly	46	2.13	.778		
Down key	Young	90	3.21	.814	14.722	.000*
	Elderly	46	1.22	.593		
Left key	Young	90	16.34	4.748	-17.683	.000*
	Elderly	46	49.48	16.543		
Right key	Young	90	25.69	6.263	-18.782	.000*
	Elderly	46	56.52	12.911		

In this study, the car racing game is used to investigate the design of control interface. Meanwhile, the control keys can be divided into two groups, steering control and speed control. The experimental results show that elderly use more times to steering control than youth and it reached a significant difference (p=.000 < 0.05). In contrast, young adults use more speed control for the acceleration and deceleration of the car than older adults. It is also reached a significant difference (p=.000<0.05), as shown in Table 2. This is because learning to play a digital game need to memory a control scheme, making decisions in time. Meanwhile, the hand-eye coordination is also required [1]. But in general, older people respond relatively more slowly than the young people. Therefore, we suggest that simpler

interface design of brain training game is more suitable for older adults.

B. Brain age reference diagram for response speed training

In addition, a brain age reference diagram, based on the playing data of participants is provided. As shown in Fig. 4 is a brain age reference diagram for training of response speed by the proposed car racing game. Data points in the leftmost of the diagram represent the average score in young people of age 18, who have a very high skill level in playing digital games (all young students are in the department of game science). They can get an average lap time of 66 seconds. In addition, the notation 66(32), the number 32 in the parenthesis is the number of participants. Meanwhile, the youth group gets an average lap time of 66.4 seconds. In contrast, the senior group get higher average lap time of 100.6 seconds. In other words, if someone gets less than 66.4 seconds in this game, its response speed will be categorized as young people. Meantime, for the fruit catching game, the average number of catching items for the youth group is 51.1 and 20.2 for the senior group in one minute.

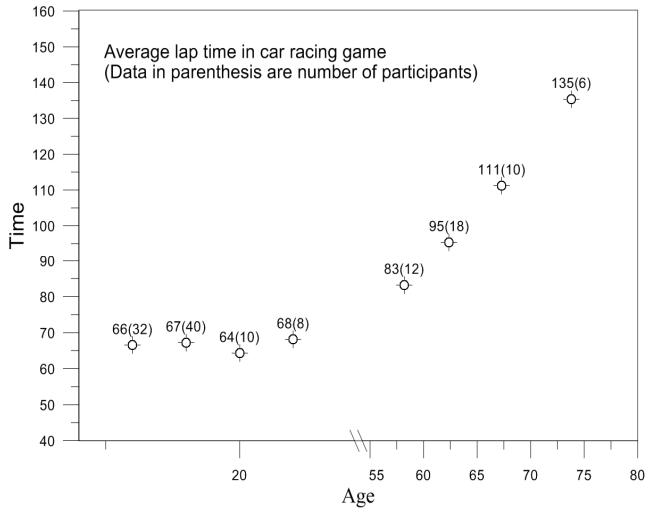

Figure 4. Brain age reference diagram for the car racing game

C. Usability measure and brain age reference diagram for problem solving games

Due to many brain training games provide variety problem solving (math) games for elderly, therefore two basic math games are developed in this study. The first one is a game for usage in daily life- the giving change game. The second one is a game for four basic arithmetic. From the survey questionnaire results demonstrated that whether young and older adults prefer the giving change game than the game of four basic arithmetic. The reason is they feel bored and have math stress in giving the correct operator in the game of four basic arithmetic.

In the game of four basic arithmetic, the usability is measured by the number of correct answers in one minute. The results show that there is significant difference between the two groups ($t = 13.420$, $p=.000 < 0.05$), as shown in Table 3. It means that young people in solving basic math problems are fast than the aged. For the giving change game, the usability is measured by the ratio of correct answers to total number of questions. To understand whether there is a significant difference in the giving change game between the young and the old group. The information of results in the two groups is reviewed, and also shown in Table 3. The results reveal that young have more accuracy in giving change than the elderly ($t = 19.128$, $p=.000 < 0.05$). From the above results, we can conclude that the problem solving ability of young adults are better than the older adults.

TABLE III. THE ANALYSIS RESULTS OF THE PROBLEM SOLVING GAMES

Problem solving	Group	No	Mean	Standard deviation	t	Sig.
Four basic arithmetic	Young	90	22.70	3.655	13.420	.000*
	Elderly	46	13.87	3.581		
Giving change	Young	90	.7294	.10368	19.128	.000*
	Elderly	46	.3661	.10701		

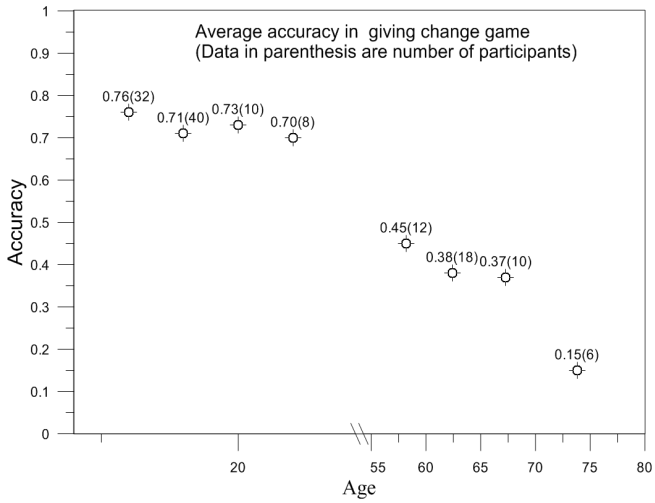

Figure 5. Brain age reference diagram for the giving change game

The brain age reference diagrams for the giving change game is shown in Fig. 6. In Fig. 5, data points in the upper left corner of the diagram represent the average accuracy of giving change in young adults. The average accuracy at least reaches 70% (age 21) or more for the youth. In contrast, seniors only get the highest average accuracy of 45% (age 55-60) or less. In addition, for the game of four basic arithmetic. The average score of young group is 22.6, far more than the 13.9 average of old group.

D. *The favorite game in young and old group*

After the end of the experiment, a feedback form on the game evaluation survey for the participants is performed. The player's favorite game survey result is shown in Table 4. The survey results indicated that the fruit catching game is loved by most of old adults (reached 52.2%). From the survey questionnaire we know that the main reason is easy to play and has no psychological burden. However, young group is more like the car racing game than others (42.2%). Since variety of control options, let young players can challenge a high score. Meanwhile, the two auto circling NPC cars let young players do not feel monotonous and bored.

In addition, comparison of two different types of games in player's experience and preference between the young and elderly are also studies. From the results of Table 4, we found that regardless of the group all players are more like the game type of training for response speed (reached 75%) than the game type of problem solving (25%). The main reason is without problem-solving stress in the game type of training for response speed. In other words, no psychological burden and simple interface design are the key factors in design popular games for brain training.

TABLE IV. THE FAVORITE GAME IN YOUNG AND OLD GROUP

Game type	**Training for response speed games**		**Problem solving games**		**Total**
	Car racing	*Fruit catching*	*Giving change*	*Four arithmetic*	Total
Young	38* (42.2%)	25 (27.8%)	17 (18.9%)	10 (11.1%)	90
Elderly	15 (32.6%)	24* (52.2%)	5 (10.9%)	2 (4.3%)	46
Subtotal	53* (39.0%)	49 (36.0%)	22 (16.2%)	12 (8.8%)	136
Total	102* (75%)		34 (25%)		136

*Favorite game

IV. CONCLUSION

Reimers and Maylor [7] demonstrated differential age effects in task-switching performance. Based on our experimental results, we found that no matter what form of games young adults finished the game task more effectiveness than the older adults. That is, our experimental results demonstrate differential age effects in playing game performance. Meanwhile, the results are strikingly similar to our previous results for comparison of game experience and preferences between young and elderly [13].

For the game interface design, the experimental results show that there is a significant group difference between the elderly and youth for control keys used in game. We found that seniors use more left and right arrow keys to modify the car direction than youths. Meanwhile, the up and down arrow keys are seldom utilized by older adults. From the interviews and observations, older adults tend to focus on control of the car in the center of the track and while collision happens elderly need more time to drive the car back to the track. Therefore, we suggest that the simpler interface design of the brain training game is more suitable for elderly.

Nacke et al [9] indicated that the type of challenge that is preferred seems to differ between young and old. In this study, both young and older groups is more prefer the game type of training for response, car racing game and the fruit catching game, than the two problem solving games, that is because they provide more amusement or enjoyment than problem solving.

The most popular game for the elderly is the fruit catching game, because it easy to control- players only need to control the left and right arrow keys while playing. Meanwhile, from the survey results revealed that more relaxed and without math stress is the reason for popularity by elderly. In addition, the brain age reference diagrams for the four developed games are proposed. Players can use these diagrams to understand their capability with respect to young and old group.

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