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VIRTUAL REALITY COGNITIVE TRAINING WITH MINDFULNESS PRACTICE

[1]WORRANITTA KRAISITTIPONG, [2]TAIZO MIYACHI

[1,2]Electrical and Electronic Engineering Department Tokai University, Japan
E-mail: [1]worranitta.mink@gmail.com, [2]miyachi@tokai-u.jp

Abstract - Cognitive impairment refers to the decrease in cognitive abilities which have a risk to develop Dementia syndrome. To prevent risk of developing Dementia, physical activities and cognitive training are profitable for improving cognitive abilities. We propose a methodology (COGT) of combination of cognitive training in a matrix of tiles by Oculus Rift and mindfulness meditation practice. We focused on memory recall with virtual reality experiences in Oculus Rift and examined mindfulness meditation effects on concentration. We could certify that all participants except one participant could easily enjoyed web-based VR application in three levels with 3 minutes mindfulness meditation practice and enhanced the ability of memory and recognition of five positions of tiles in a space of a matrix of 16 tiles. After mindfulness meditation practice, all participants could acquire higher score with lower heart rate and shorter duration.

Keywords - Virtual Reality, Cognitive Training, Mindfulness, Oculus Rift, Myo Armband, Heart Rate.

I. INTRODUCTION

Dementia is a syndrome that refers to decrease in memory and mental ability severe enough to damage activities of daily living (ADLs or ADL) (e.g. grooming, dressing and taking medicine). It is associated with Alzheimer disease (AD) and Parkinson's disease with dementia (PDD). Among dementia syndrome cases, 60-80% was diagnosed as Alzheimer disease[1]. With increasing age, normal adult develops mild cognitive impairment (MCI) which leads to Alzheimer syndrome[2].
To avoid cognitive impairment, aerobic physical activities and cognitive training are effective for keeping cognitive function healthy and delaying progress of dementia with mild cognitive impairment[3][4]. Cognitive training enables a participant to improve cognitive abilities such as attention, perception, memory, language, learning, and higher reasoning. Mindfulness meditation can be found in various cultures and religions. It originally came from Buddhist culture. It has been modified in multiple forms such as Vipassana meditation, yoga and Zen. The purpose of mindfulness meditation is to train the mind while improving psychological capacity, such as attention, self-regulation and emotion control. However, there is appending evidence that mindfulness meditation may cause neuro plastic changes in structure and brain function that involve emotion, regulation of attention and self-awareness [6]. Virtual reality (VR) is a new technology that simulates a real world including stereoscopic senses of human such as sense of vision, sense of hearing or sense of touch. VR can be represented as a monitor or a screen or head mount display. The advantage of VR is bringing media closer to real life. We propose a methodology of memory training and memory recall by virtual reality experiences with head mount display (HMD) and its effectiveness on mindfulness meditation.

II. COGNITIVE TRAINING SYSTEM

There are several games that are effective for the dementia. For example, there is research proof that Nintendo Super Mario 64 increases hippocampal grey matter in older adults, which is vital for learning new skills and playing such games may result in brain growth in younger adults[8]. Three-dimensional platform videogames and logic game was associated with grey matter in the hippocampus which improves brain capacity and help prevent dementia.

However, Nintendo games may found difficult for some person (e.g. sensitive person, elderly person).

Problem1: A sensitive person feels uncomfortable. Problem2: The problem with preparing the game machine. Problem3: The person has to remember many operations on game. Problem4: The person has trouble with long concentration. Problem5: The game is excessive complex to understand.

III. EASY COGNITIVE TRAINING SYSTEM WITH MINDFULNESS

Many experiments have shown the effective of Role Playing Game (RPG) for cognitive health benefits that avoid Dementia syndrome[13]. However, there are many persons that cannot easily enjoy RPG games since they cannot do timely operations corresponding to quick events. We propose an easy cognitive training system (COGT) that is simple for general ages including elderly person and children. COGT has memory training functions on a space of a matrix of tiles. COGT also enable a user to space recognition training and quick operations on the space. COGT

has seven major characteristics in order to avoid dementia and delay the progress of dementia.

(1) Easy start and simple operations by hands and arms.

(2) Enhancement of memory. Improve the ability of remembering relative positions of many tiles.

(3) Recognition of 3D space. Improve the ability of recognizing 3D space with relative positions of multiple tiles and their pattern in a large tile matrix. A user can train attention to various spaces such as up and down, left and right.

(4) Fast thinking and operation with feeling attainment. Improve the ability of rapid remembering green tiles, thinking of the order of actions, and quick selecting the tiles. Enjoy a quick success signs in continuous attainments.

(5) Concentrate and repeat correct operations in a large matrix of tiles

(6) Take a rest with a mindfulness exercise. By controlling their breath for three minutes before next training to reset the concentration and clam their mind.

(7) Easy preparation by Oculus Rift. A user can comfortably use COGT anywhere in "Flow state".

We propose COGT to improve the ability of memory, 3D space recognition, quick thinking and operation with arms and hands, tracing changed color tiles with a series of associated number, emotion for feeling mindfulness and attainment. We also analyze the relationship between biological data and the improvement of concentrated operations.

3.1 Environment setup for experiment

Before experiment, we have trained participants to use Oculus Rift (HMD) and one Oculus Touch controller. A participant wear Myo armband for detecting their muscle data and Mi band 3 for their heart rate data on their dominant hand (Refer to Fig. 1).

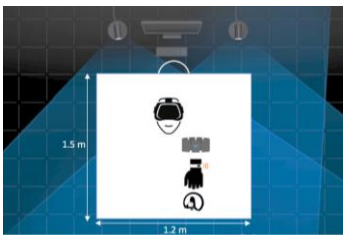

Fig.1. Virtual reality application environment setup

Oculus Rift for displays immersion VR environment and Oculus Touch controller on the dominant hand for controls virtual hand in VR application.

3.2 Website-based VR application

The website-based VR memory training game has been created with react-VR framework from Facebook, to associate with head mount display named Oculus Rift for simulating the virtual world and we requested participants to play the game. On VR application program was full immersion by using Oculus Rift. This Application required Windows 10 or newer Operating System, Intel i3-6100 or greater central processing unit (CPU), more than 8 gigabyte random access memory (RAM) and equivalent NVIDIA GTX 1050Ti or greater graphic card (GPU).

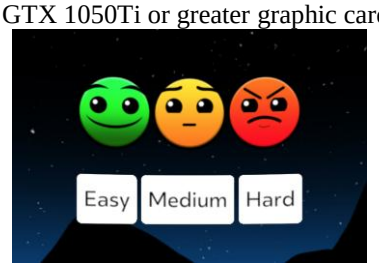

Fig.2. Level selection page

Participants can choose one level among three levels, such as easy, medium and hard. On each level, participants had to remember the tiles that changed color. A participant remember three tiles in a matrix of 3 * 3 tiles and chooses the correct three tiles in the matrix in easy level (Refer to Fig 3). A participant remembers five tiles in a matrix of 4 * 4 tiles and chooses the correct five tiles in the matrix in medium level (Refer to Fig. 4). A participant remembers seven tiles in a matrix of 5 * 5 tiles and chooses the correct seven tiles in hard level (Refer to Fig. 5).

Fig.3. Easy level with 3x3 tiles

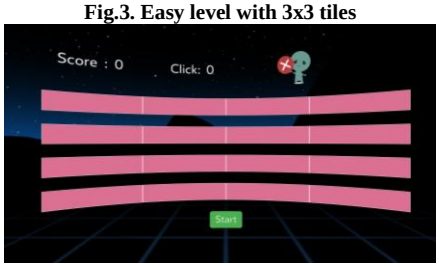

Fig.4. Medium level with 4x4 tiles

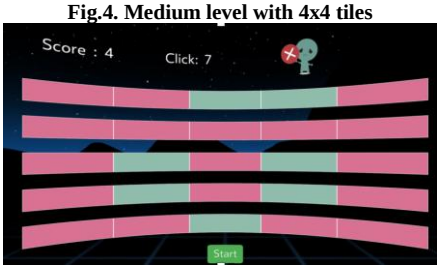

Fig.5. Hard level with 5x5 tiles

The procedures of the experiment are as follows:

P1. Choose one level.

P2. Press the start icon. COGT shows randomized green tiles in a set of pink tiles.

P3. A participant remembers the positions of green tiles.

P4. The participant chooses the positions in any order in the set of pink tiles.

P5. When the participant can choose all randomized green tiles, COGT shows a new set of randomized green tiles in the set of pink tiles.
The participant repeats P3, P4, and P5 in the chosen level.
P6. The participant moves to a next higher level, such as medium level and hard level, and repeats P3, P4, and P5 in each chosen level.
P7. The participant enjoys a mindfulness meditation.
P8. The participant repeats the same cognitive training as P3, P4, and P5 in a next level.
In the VR memory training game, a participant has to remember the randomized tiles and meanwhile remember the number of tiles that participants had already selected. Therefore, We have selected pink as the normal tiles and green as the randomized tiles because according to color wheel, the opposite color of pink is green and it was predicted that the higher level of contrast can influence memory retention, attract more attention and gain visibility of an object or information[7].
After the first run, participants desired to do a mindfulness meditation practice where they sat quietly in an erect posture, relax and maintain their breath. The steps included breathing in for 4 seconds by nose, hold the breath for 5 to 7 seconds and breathe out for 5 to 8 seconds by mount and then repeated the game[12].

Fig.6. Participants during experiment

3.3 Biological data

A Mi band 3 by Xiaomi used to collect the heart rate data and Myo armband by Thalmic labs used to collect the electrical activity of the muscle or electromyography.

IV. EXPERIMENT

The VR memory training is a simple game for general ages so that either children or elderly person would be able to participate.

4.1 Participants

There were 10 participants in this research. All participants were the volunteers from graduated students at Tokai University, Shonan campus, Japan.

Participants	*Characteristics*			
	Gender		*Mean age*	*Mean education in years*
	Male	Female		
Graduated Students	8	2	24.8	20.6

Table1: Characteristics of participants

Characteristics of participants are shown in Table 1. The volunteer students were 10 persons (8 men and 2 women). Mean age of participants was 24.8 years in range of 24 to 27 years. Mean education in years of participants was 20.6 years in range of 20 to 22 years. All of participants are right-handedness.

4.2 Memory ability of participants

From the VR memory application, we recorded the result and calculated average data. For accuracy scores, we calculated as a percentage and for average time we calculated as a second.

Level	*Minimum score*		*Average score*		*Maximum score*	
	Before	**After**	**Before**	**After**	**Before**	**After**
Easy *(High score:30)*	29	30	29.9	30	30	30
Medium *(High score:50)*	46	48	48.3	49.4	50	50
Hard *(High score:70)*	54	56	61.4	64.8	66	70

Table2: Accuracy data of participants

Fig. 7 shows the accuracy percentage of participants. Accuracy score had average percentage in easy level before mindfulness medication practice = 99.67 percent, easy level after practice = 100 percent, medium level before practice = 96.6 percent, medium level after practice = 98.8 percent, hard level before practice = 87.71 percent and hard level after practice = 92.57 percent.

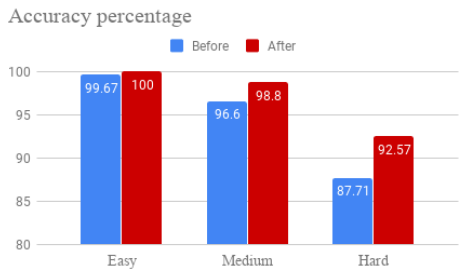

Fig.7. Accuracy score in percentage

All participants had achieved the perfect score in the easy level after mindfulness meditation practice (Refer to Table. 2 and Fig. 7). All participants could recognize the space of matrix 3 * 3 tiles and remember three randomized tiles. Easy level training was very effective for a participant with the lowest memory ability.
The lowest ability participant got 48 for perfect score 50 in the medium level after mindfulness meditation practice. This means that all participants could recognize the space of a matrix (4 * 4) tiles in the medium level. The lowest memory ability participant could not remember one tile of five tiles. The meditation practice was effective and enabled the participant to remember one more tile in the medium level. Minimum score in hard level was 54 and 56 (after mindfulness meditation practice). The average score in hard level was 61.4 and 64.8 (after mindfulness meditation practice) for perfect score was 70. This means that it was difficult for ordinary participants to remember seven tiles. Recognition of a

space of a matrix of 25 tiles (5 * 5) was also difficult. Remembering seven correct positions on a matrix of 25 tiles (5 * 5) was very difficult since the magical number in short term memory of human is 7 ± 2[11].

Maximum of average score after mindfulness meditation was 64.8 for the perfect score was 70 in hard level. This means that ordinary participants could not remember the exact space of the matrix of 25 (5 * 5) tiles. They misrecognized two or three positions of seven target tiles in the matrix of 25 (5 * 5) tiles although the mindfulness meditation enabled ordinary participants to remember one or two more correct positions of the seven tiles (Refer to Fig. 7). However, one excellent participant could get four more points by mindfulness meditation and get the perfect score. The mindfulness meditation was effective for the excellent participant so that he could remember seven tiles and relationships of their correct positions among seven tiles in the matrix of 25 (5 * 5) tiles.

Level	*Minimum duration (seconds)*		*Average duration (seconds)*		*Maximum duration (seconds)*	
	Before	**After**	**Before**	**After**	**Before**	**After**
Easy	20	23	43.2	31.7	71	41
Medium	39	39	64.9	52.2	85	61
Hard	67	53	105.5	77.8	128	122

Table3: Duration data of participants

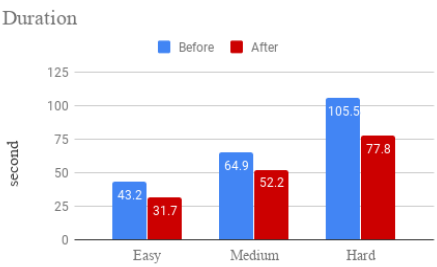

Fig.8 Average duration

Duration before and after mindfulness meditation practice are shown in Fig. 8. Average time in easy level before practice = 43.2 seconds, easy level after practice = 31.7 seconds, medium level before practice = 1:04 minute, medium level after practice = 52.2 seconds, hard level before practice = 1:45 minute, hard level after practice = 1:17 minute.

The mindfulness meditation had slightly effects on accuracy but very effective on duration. Participants spent quite shorter time after mindfulness meditation practice. In hard level, decrease of duration after mindfulness meditation became the highest because most participants could roughly guess the positions of randomized tiles.

Level	*Efficient case*				*Normal case*			
	Duration (seconds)		*Score (percent)*		*Duration (seconds)*		*Score (percent)*	
	Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Easy	35	34	100	100	51	33	100	100
Medium	60	50	98	100	85	58	94	96
Hard	93	77	90	100	98	92	81.4	80

Table 4: Efficient case and normal case

We have selected one of the most efficient participant and normal efficient participant (Refer to Table 4). Even though both of the case has no experiences on VR application before, the efficient participant had generally played game so it was easier to felt familiar with our application. However, the normal case participant was not regularly played game so it was more difficult to get familiar with our application but after easy level it became better. On the first run, both spent closely duration on hard level, after mindfulness meditation both of the case spent less time and the efficient case get higher score on medium and hard level. The normal case got higher score on medium level and lower score on hard level but most of the case got higher score after mindfulness meditation and also spent shorter time.

4.3 Biological data of participants

During experiment, we have recorded the heart rate data and electromyography. From the raw data, we have extracted each variable and analyze to the chart. Fig. 9 and Table5 show the average heart rate of participants before and after mindfulness meditation practice. Average heart rate in easy level before practice = 85.59 bpm, easy level after practice = 72 bpm, medium level before practice = 90.44 bpm, medium level after practice = 82.81 bpm, hard level before practice = 90.19 bpm, hard level after practice = 89.22 bpm.

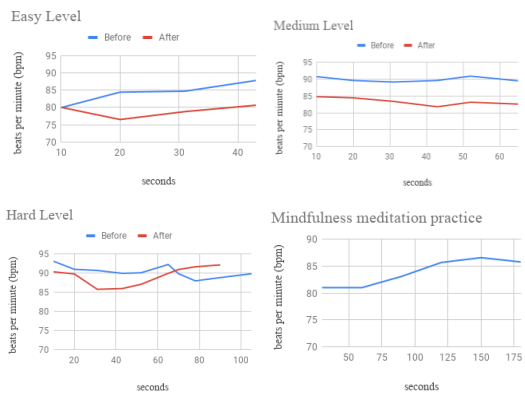

Fig.9. Average heart rate data during experiment

Level	*Minimum heart rate data (bpm)*		*Average heart rate data (bpm)*		*Maximum heart rate data (bpm)*	
	Before	**After**	**Before**	**After**	**Before**	**After**
Easy	68.42	60.2	85.59	72	105.25	88
Medium	63.33	58.43	90.44	82.81	120.4	99.2
Hard	71.71	64.44	90.19	89.22	111.08	103.53

Table5: Heart rate data of participants

During enjoy the application, heart rate has constantly increase especially before the mindfulness meditation practice and slightly decrease after mindfulness meditation practice. Also, heart rate constantly increasing by the difficulty of the application which means participants feel excited during enjoy our application. Fig. 10 shows the electrical activity of the muscle of participants. Most activation early

happened and the activations were sustained after mindfulness meditation practice in medium level.

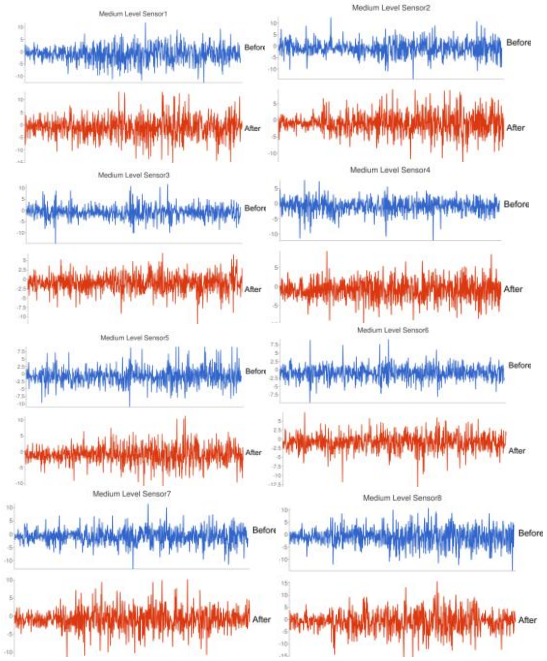

Fig.10. Average electromyography in medium level

4.4 Questionnaire

We questioned participants about satisfaction of using our VR application about difficulty of applications, their experiences on VR application and effectiveness of mindfulness meditation.

Fig. 11 shows the opinion of difficulty on each level of our application. At easy level, participants though it too easy 4 persons (40%), quite easy 5 persons (50%) and appropriate 1 person (10%). At medium level, participants though it too easy 1 person

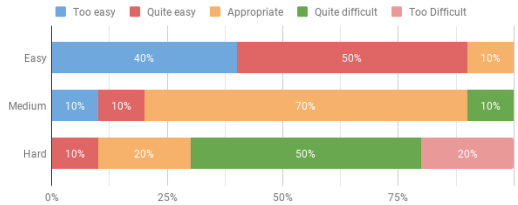

Fig.11. Difficulty of application on each level

(10%), quite easy 1 person (10%), appropriate 7 persons (70%) and quite difficult 1 person (10%). At hard level, participants thought it quite easy 1 person (10%), appropriate 2 persons (20%), quite difficult 5 persons (50%) and too difficult 2 persons (20%).

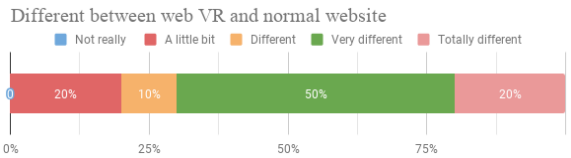

Fig.12. Participants opinion on web VR and normal website

Fig. 12 shown participants' opinion of using web VR with HMD and controller compare to normal website. Participants 2 persons (20%) though there is a little bit different, different 1 person (10%), very different 5 persons (50%) and totally different 2 persons (20%).

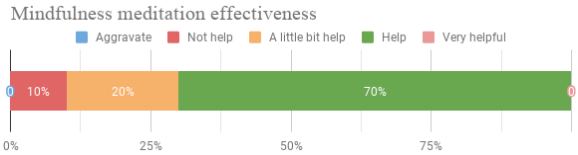

Fig.13. Participants opinion on mindfulness meditation effectiveness

Fig. 13 shows participants' opinion of effectiveness after mindfulness meditation practice. Participants thought it not help 1 person (10%), a little bit help 2 persons (20%) and help 7 persons (70%).

According to the evaluation, majority participants thought that easy level was either too easy or quite easy for them, on medium level was appropriate and on hard level was difficult. We had interviewed participants and we have got some suggestions as follows. Firstly, using VR headset was hard for person who had eyesight problem. Secondly, our application was new experiences for them. Thirdly, because of VR headset they felt immerse unlike normal website. Fourthly, with VR experiences they felt more interaction and movement. Lastly, they though the mindfulness meditation helps them reset their concentration. Participants mostly thought that mindfulness meditation practice did help them concentrate and clam their mind before playing VR application. Nonetheless, participants 70% thought that VR experiences is very different to totally different from the normal website because the immersive feeling of VR made participants enjoyed more and also reduce the interruption of the environment so they were more concentrate on the application.

V. DISCUSSION

D1. Heart rate data became lower after mindfulness meditation practice in both easy and medium level. Participants also reduced the duration and got higher score after mindfulness meditation. Participants felt calmer after mindfulness meditation. The hard level increased the duration which means increase of tiles to be remembered also increased the time for recalling memory. Although the record of 8-channel arrangement of EMG signal had shown insignificant difference, participants had continuous muscle movement which might enhance fitness and physical activity.

D2. COGT in both easy and medium level provided participants with effective cognitive training that enhanced the ability of both memory and recognition of the space of a tile matrix. The effects might reduce the risk of developing dementia syndrome in either

healthy adult or person with cognitive declination. We should expand the experiments to elderly persons.
D3. Mindfulness meditation was very effective in cognitive training program. We should find easier and shorter mindfulness meditation practice.
D4. The job of remembering seven tiles in the matrix of 25 (5*5) tiles was too tough for most participants. Multiple colored matrix and recognition by grouping should be introduced.
D5. Most participants could enjoy the application with immersive feeling of VR. Some participants felt uncomfortable with Oculus Rift by simulator sicknesses. We should introduce the ways to reduce the sicknesses (e.g. virtual nose or Nasum Virtualis[10]).

VI. CONCLUSIONS

We proposed an easy cognitive training methodology COGT with web-based VR application in terms of enhancement of the ability of both memory and recognition of a matrix space. We could certify the effects for young participants that included both healthy person and cognitive decline person. COGT was effective to reduce the risk of developing dementia syndrome. We also certify the effect of calmness and jolliness by mindfulness meditation in cognitive training.

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