

Effects of Casual Computer Game on Cognitive performance through Hemodynamic Signals

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Abstract. Intervention of the cognitive declines process is essential. Computer game has been assumed to give effects on activation of brain activity. However, there are many types of computer games. At the same time, the brain activation can be understood through the brain signals. In this study, we present the changes of cognitive performances through the scores of neuropsychological testing after the entertainment of casual puzzle game. Our controlled experiment was done with seven participants. The evidence showed the better performance in spatial imaginary and perceptual speed ability, yet unstable performance in working memory and attention through the task of finding different items after the computer game entertainment. Moreover, we then illustrated the changes in hemodynamics signals derived by using a wearable functional-Infrared spectroscopy (fNIRS). Median of max-min normalized oxy-Hb and the power spectral density indicated the small variation of brain activation after involving into the casual puzzle game playing.

Keywords: Cognitive performance, fNIRS, oxygenated hemoglobin signals, stroop task, mental rotation task, power spectral density, normalization.

1 Introduction

Declining of cognitive performance does not always happen to the elderly but sometimes to younger adults [1]. Enhancing the cognitive capacity is essential in order to intervene the process of cognitive decline.

Affectivity is likely to have association with changes in cognitive performance. For example, the previous study indicates that the negative affectivity such as perceived stress and depression have influences on the rapid process in cognitive decline among elderly [2], [3]. On the other hand, involving into activities that stimulate positive arousal has been suggested to enhance cognitive ability through working memory [4]. Computer game provides fun and entertainment that lead to positive arousal and was claimed to be beneficial on cognitive abilities [5]. However, each type of computer game might have different effects on the different domains in cognitive performance. Previous studies conducted the experiment with action game and claimed that the video action game can enhance cognitive performance[6]. However, investigating other types of games and cognitive

abilities are still remained for further studies. Thus, investigation of computer games to fulfill the applicable knowledge to support the early intervention and therapeutics of cognitive decline is needed.

The phenomena relating to affections and cognitions in neuroscience studies are understood through activities of brain signal such as electroencephalogram (EEG), functional magnetic resonance imaging (fMRI), and near-Infrared spectroscopy (NIRs). Emotion status was understood regarding the EEG signal patterns [7], while cognitive abilities among Alzheimer patients can be observed through MRI [8], [9]. Moreover, hemodynamic oxygenation changes via NIRs were also investigated during brain activities in patients [10]. Brain signals now provide promising sources. It is believed to be an effective tool for monitoring brain activities during various mental tasks, entertainment activities and social events.

In this paper, we focus on the brain oxygenated hemoglobin signal during the mental tasks before and after playing a computer-based casual puzzle game. The computer-based puzzle game is addictive and easy to play, at the same time, it provides dimensions for a player to activate more on his brain function. We hypothesize that the effects of playing computer games can be reflected through oxygenate hemodynamic of brain. Additionally, the casual puzzle game might improve performance of cognitive function. The cognitive domains investigated in this paper include cognitive flexibility via stroop task, visuo-spatial ability via mental rotation task, memory capacity via pair association task, and attention ability via finding difference task.

2 Method

2.1 Subject

The study initially recruited seven subjects. The subjects are students at Japan Advanced Institute of Science and Technology. They are considered as healthy subjects due to the non-clinical history related to brain, and neurological, psychiatric and cardiovascular disorders. The mean age of subjects is 27 ± 3.8 and three of all subjects are male.

2.2 Neuropsychological testing

Neuropsychological testing is one of performance-based methods to assess a wide range of cognitive functioning and ability. For neuropsychological test in this study, stroop task and mental rotation are used.

Stroop task was originally developed since 1993 [11]. It was used widely in various research purposes under cognitive psychology domain [14], [13]. The study recruits the stroop task to measure the perceptual processing speed ability. We use PsyToolkit “psytoolkit.org/” [15], [16] as a tool to demonstrate a computer-based stroop task experiment. Aside, mental rotation task, whose concept was first introduced in 1971 by Shepard and Metzler [17], was used to examine the

visuo-spatial ability of each subject before and after the puzzle game. Mental rotation task in this study is to rotate a mental representative of two dimensional objects.

Moreover, some additional tests of attention and memory were also taken. The additional memory test is an associated pair matching game. This game allows subjects five seconds to remember 9 position of 3 pairs of pictures. Then, the subject was asked to match each picture with its pair on a correct position. Another game for testing attention is finding different item among the group. The subject was given sets of pictures. The subject was required to pick a different picture among each set.

2.3 Optical topography fNIRs device

To observe changes of hemodynamic signal in the prefrontal cortex, we used fNIRs wearable optical topography WOT 220, manufactured by HITACHI. The fNIRs allows us to observe both oxygenated hemoglobin (Oxy-Hb), and deoxygenated hemoglobin (deoxy-Hb) blood flow in the cerebral prefrontal cortex. The measurement consists of 22 channels to capture the signals on the cortex. The fNIRs optical WOT 220 is non-invasive device, which is light weight and easy to wear on subject's head. The device supports the real-time monitoring on an event in which the subject can freely move his body during the experiment.

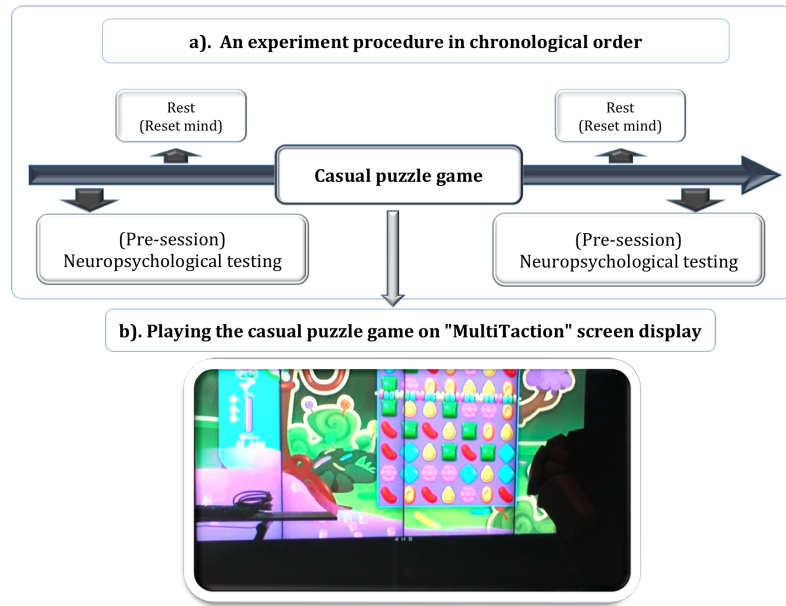


Fig. 1. An overview of experimental procedure

2.4 Experimental procedure

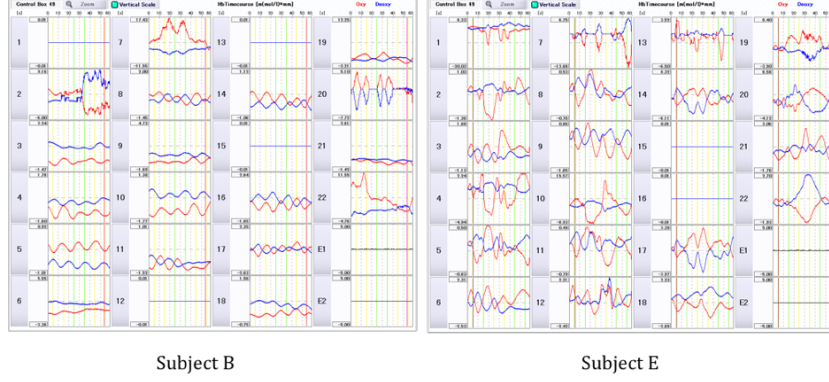


Fig. 2. Sample data of hemodynamic signal from subject B and subject E

After obtaining the consent, each subject was asked to wear the fNIRS device through the whole experiment, and sit in front of the computer display screen. During wearing fNIRS device, each subject was ensured not to lower and raised his head during each session in order to avoid noisy signals. As shown in picture a) of the Fig. 1, the experiment includes three main sessions: pre-neuropsychological test as a pre-session before the casual game playing, casual puzzle game playing, and post-neuropsychological test as a post-session after playing the casual puzzle game. The casual puzzle game used in this experiment is “Candy Crush Soda Sugar”. Each subject was asked to play this casual game for 20 minutes on “MultiTaction” device, the window operating system with 55-inch wide (16:9) Full HD 1920 x 1080 screen display as shown in picture b). of Fig. 1. Moreover, between each session during the experiment, the mind is reset by closing eyes and doing inhale-exhale for 3 rounds.

The experiment was held in a specific room with a quiet environment, where there were only subjects and researcher.

3 Data Acquisition

3.1 Data of cerebral blood flow

With WOT-220 HITACHI device, the cerebral blood flow including oxygenated and deoxygenated hemoglobin signals with 22-channels were retrieved. Some channels do not work well due to the intervention of hairs and other physical condition of each individual. As shown in the Fig. 2, the left-side picture shows the hemodynamic signals in cerebral prefrontal cortex of subject B, in which

the channel 1, 12, 13, and 15 did not capture well the brain signals. The right-side picture of the Fig. 2 shows the hemodynamic signals of subject E, of which only channel 15 and channel 16 did not work well. The red lines indicate the changes of oxygenated hemoglobin (Oxy-Hb) on each channel, and the blue lines show deoxygenated hemoglobin (deoxy-Hb) of cerebral prefrontal cortex on each channel. This study, however, focuses only on oxy-Hb signals.

3.2 Normalization of oxy-Hb

In order to do a simply observation of the changes of signal between pre and post session of the casual game playing, we first implement the measurement by computing the median of the normalized oxy-Hb in both pre session and post session. The oxy-Hb signal in channel- n of subject i was nomrlized with max-min normalization approach with the following equation:

$$OxyHb'_{i_n} = \frac{OxyHb_{i_n} - \min(i_n)}{\max(i_n) - \min(i_n)}$$

Where $\min(i_n)$ is the minimum value and $\max(i_n)$ is the maximum value of oxy-Hb signal in channel- n of subject i through each neuropsychological test session (pre-session and post-session).

Each signal is considered as a vector V that contains k component (with k length). The median value of each normalized signal was generated by sorting data component of each signal in ascending order and then, when k length is an odd number, the middle value of a signal is $\frac{(k+1)}{2}^{th}$. And, the median of a signal is computed by the average of two middle values, when k length is an even number.

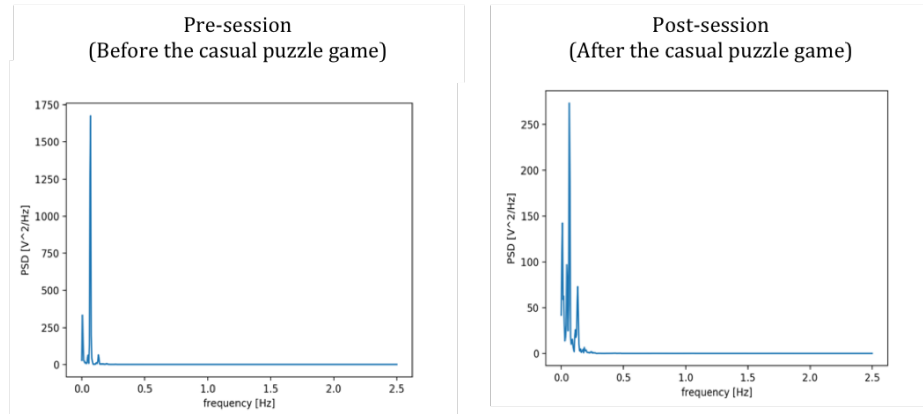


Fig. 3. The power spectral density of subject G during the mental tasks through neuropsychology testing before and after playing the casual puzzle game

3.3 Power spectral density

The power spectral density (PSD) is a point estimation of the energy variation in time series signal data as a frequency function. In this study, we compute the PSD based on Welch's method [18]. The PSD is determined by averaging the windowed periodogram [19]. Regarding the Welch method, the original sequence signal is divided in multiple overlapping segments. Then, the Welch method computes an array for each segment, in which each element is an average of the corresponding elements of all divided segments.

We computed PSD to extract maximum energy as the strongest variance of the oxy-Hb signal of each subject during the neurological testing in pre-session (before playing a casual puzzle game), and in the post session (after playing a casual puzzle game). We implemented on python with library SciPy. An example of the PSDs generated from oxy-Hb signal in channel 22 of subject G during his mental tasks in pre-session and post-session are shown in Fig. 3.

4 Result and discussion

4.1 Cognitive performance through neuropsychological testing

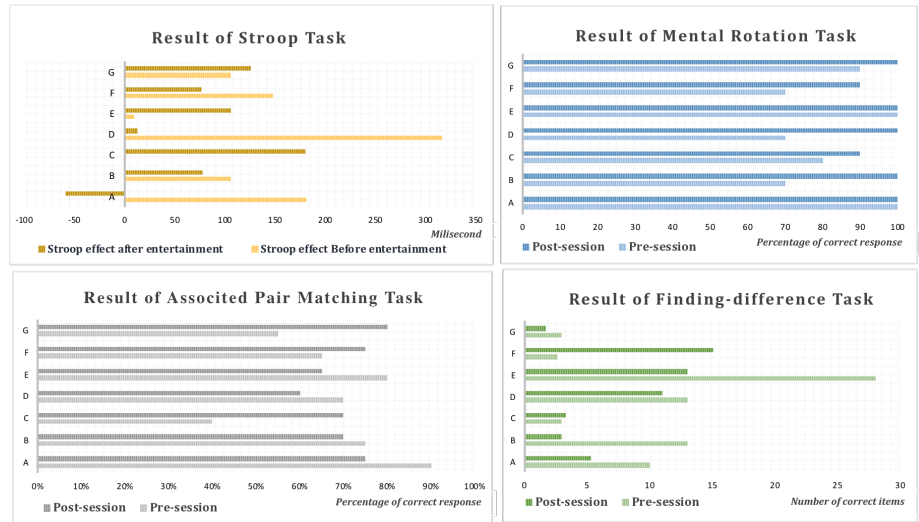


Fig. 4. Scores of neuropsychological testing

Fig. 4 shows the scores of neuropsychological testing. The results show that after a casual puzzle game playing, the ability of visuo-spatialization has been obviously improved, when the evidence through a mental rotation task shows the

number of correct responses from each subject increased with less responding time (see top-right chart of Fig. 4). Similarly, stroop effect of each subject after enjoying the causal game was likely to be reduced. The score of stroop effects was computed by the average speed in correct trails of incongruent minus that in congruent. The smaller scores of stroop effect refer that individuals is faster in naming the color of ink a word is [22]. According to the top-left diagram of Fig. 4, 60% of subjects produced lower stroop effects after playing the puzzle game. This phenomenon might refer that each control subject have the speed improvement of perceptual function after enjoying the casual puzzle game. In contrast, visaul attention ability through finding different picture was dropped down. Meanwhile, the scores from experiential result did show unstabe trends of memory performance through associated pair matching game task.

4.2 Oxy-Hb signal analysis

To illustrate the individual level, Fig. 5 shows the median values of the normalized oxy-Hb from 22-channels fNIRs for each subject during the mental tasks through neuropsychological testing before and after playing a causal puzzle game. It is shown through the Fig. 5 that median value is missing from some channels due to the intervention of subjects' physical conditions. Thus, the common channels that well extacted hemodynamic signals from all subjects were considered to monitor the changes of brain activation in the population level.

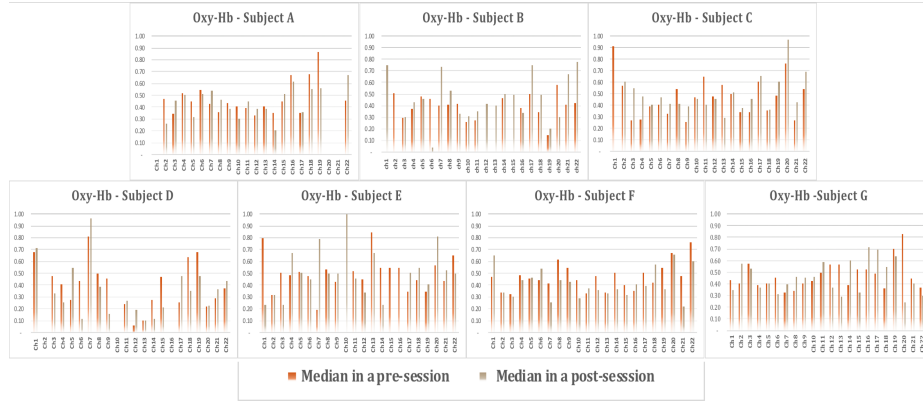


Fig. 5. Median of normalized oxy-Hb signals in 22-channel fNIRs by each subject

The channel 3, 9, 14, 19, and 22 are representatives to illustrate the changes of brain activation in this study. The change is generated by the middle values of normalized oxy-Hb signals after a causal game playing minus those before a game entertaining. The minus values of changes indicated that the medians

of the normalized oxy-Hb signals after the casual game are smaller than those before the casual game as shown in the Fig. 6.

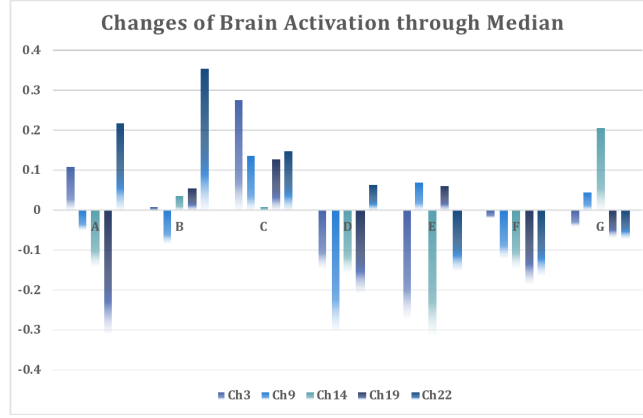


Fig. 6. Changes of brain activation through middle values of normalized oxy-Hb

The Fig. 6 shows an interesting results when all subjects excluding subject C have decreasing middle values of the normalized oxy-Hb.

Additionally, the power spectral density (PSD) of oxy-Hb signals also significantly changed after the casual game playing. The energy variation of oxy-Hb signals were reduced in the post-session, especailly, channel 19 shows a big difference of the strong varaince of oxy-Hb before and after the causal game playing.

Previous work through fNIRs-based signals indicated brain activations during a mental task of healthy control are higher than those in schizophrenic patients [21]. On the other hand, the study of observing mental workload through different levels induced the brain activations in middle and difficult level of mental tasks are higher than those in easy level [20]. In our case study with healthy control, the changes of oxygenated hemoglobin through middle values and PSD were slightly reduced while cognitive performance in mental rotation and stroop task were gradually improved.

The lower in PSD and middle values of oxy-Hb might induce the release of workload in brain function after the computer game entertainment. However, from the evidence of our experiment, indicating the correlation between oxy-Hb changes and cognitive performance is still in ambiguity. The PSD and middle values only indicated the changes of the brain activation before and after the computer casual game, while in order to clarify the relation between cognitive performance and oxygenated hemoglobin signals, the study requires larger number of samples. Moreover, our limitation in this study also related to the invetigation of fNIRs signals on four mental tasks without seperation on each task. Each mental task, for examaple mental rotation, stroop task, associated

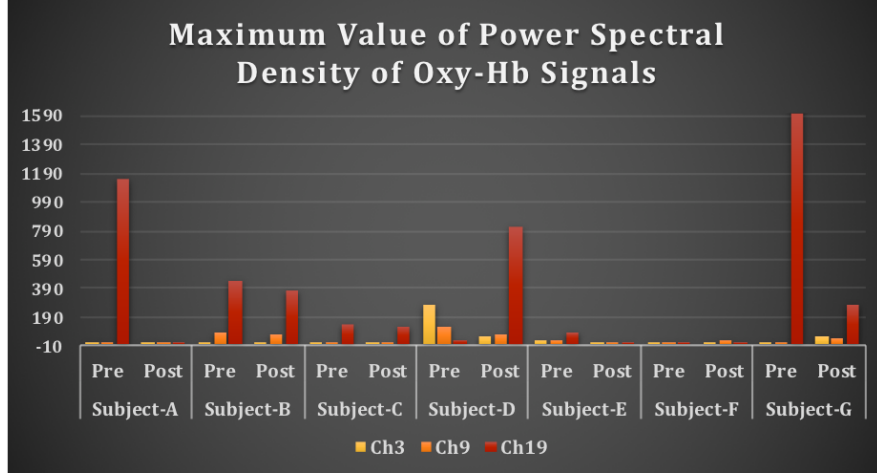


Fig. 7. Changes of brain activation through power spectral density

pair matching task as well as finding difference task, has its own characteristics, and might require different pattern of brain activation. If the oxy-Hb signals had been investigated in each single mental task, the changes of oxy-Hb signals on a particular domain of cognitive performance would be obtained and more clearly explained.

5 Conclusion

In this paper, we investigated the cognitive performance before and after the entertainment through playing the casual puzzle game. We also investigated whether the brain activation is influenced by the casual puzzle game playing. The study suggested that the casual puzzle game in the form of computer version improve an immediate capacity of cognitive flexibility and visio-spatial ability, however, the short-term memory and fast eyes capacity are still in ambiguity. Moreover, the investigated features such as median of max-min normalized oxy-Hb and the power spectral density of oxygenated hemoglobin signal show the differentiation of brain activation in which oxy-Hb signals after a casual game playing have smaller variation comparing with those before the casual game. In order to infer the relation of oxygenated hemodynamic changes and the cognitive ability improvement, and understand the cognitive performance changes through oxy-Hb signals, we plan to extend our future study with larger population together with comprehensively investigate oxy-Hb signals on each type of cognitive ability, individually. Importantly, the advanced statistical machine learning approach to interpret the changes of fNIRs oxy-Hb signals on cognitive performance is considered to be employed.

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