Consideration of Measuring Human Physical and Psychological Load Based on Brain Activity

Hiroaki Inoue[1(✉)], Shunji Shimizu[1], Ishihara Hirotaka[1], Yuuki Nakata[1], Hiroyuki Nara[2], Takeshi Tsuruga[3], Fumikazu Miwakeichi[4], Nobuhide Hirai[5], Senichiro Kikuchi[6], Satoshi Kato[6], and Eiju Watanabe[6]

[1] Tokyo University of Science, SUWA, Nagano, Japan
jgh12701@ed.tus.ac.jp, shun@rs.suwa.tus.ac.jp

[2] Hokkaido University, Sapporo, Japan
nara@ssc.ssi.ist.hokudai.ac.jp

[3] Hokkaido Institute of Technology, Sapporo, Japan
tsuruga@hit.ac.jp

[4] The Institute of Statistical Mathematics, Tachikawa, Japan
Miwake1@ism.ac.jp

[5] Tokyo Medical and Dental University, Bunkyo, Japan
nobu@nobu.com

[6] Jichi Medical University, Shimotsuke, Japan
{skikuchi,psykato}@jichi.ac.jp,
Eiju-ind@umin.ac.jp

Abstract. In Japan and developed countries, it has become aged society, and wide variety welfare device or system have been developed. But these evaluation methods of welfare device or system are limited only stability, intensity and partial operability. Because of, it is not clear to determine the standard to evaluation for welfare device or system of usefulness. Therefore, we will attempt to establish the standard for evaluation about usefulness for objectively and quantitatively for including non-verbal cognition. We examine the relationship between human movements and brain activity, and consider the evaluation method of welfare devices and systems to measure the load and fatigue which were felt by human. In this paper, we measure the load for sitting and standing movement using NISR. We tried to make sure for the possibility of the quantitatively estimation for physical or psychological load or fatigue by measuring of brain activity using NIRS (Near Infra Red Spectroscopy). As results, when subjects perform the movement task, the statistical significant difference was shown in the specific part of the brain region.

Keywords: NIRS · EMG · Welfare technology · Useful welfare device evaluation

1 Introduction

As it has been known widely, aging population in Japan and world-wide countries has been increasing. Thereby the number of care worker has been increasing. Care is very

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hard work. Welfare devices and systems reducing a burden of the care work are required. In this background, welfare systems and device are rapidly developing, and various devices are manufactured based on the increased popularity of welfare device and system. Also, the market of welfare devices and systems is expanding. However, the evaluation method is limited respectively to stability, strength and a part of operability for individual system or device. It means that evaluation methodology for usefulness of them was not established. Therefore, we will attempt to establish a standard to evaluate the usefulness for objectively and quantitatively on the basis of cognition such as physical load, reduction of fatigue and postural stability. Especially, in considering universality, it is necessary to measure human movement in daily life. Movement was not measured by using particular device, but routinely-performed movement in daily life.

Recently, technology of measuring brain activity is progressed. Previous measurement apparatus limited subject's posture and experimental condition. NIRS has little such limitation in posture and the experiment condition. Because there was such advantage, we used NIRS in this study (Fig. 1).

2 Experimental Method

2.1 Evaluation by Using NIRS

We measured brain activity during motion with the purpose of establishing evaluation method based on generality (Fig. 2).

Subjects were six males aged twenties. They were asked to read and sign an informed consent regarding the experiment. Measurement apparatus was NIRS (SHIMADZU CO. Ltd products-FOIRE3000 [4]). Measurement region was at right and left prefrontal cortex.

Measuring Brain Activity During Transfer with Standing Position (Task1). At this measurement, the subjects used welfare device to perform transferring in a standing position. In this measurement, subject sat on seating face of welfare device appeared on the top of chair after raising hip until sitting posture in an invisible chair. Also, subject performed inverse transferring from seating face to chair. Time design was rest(5 s), task(10 s), and rest(5 s). This time design was repeated 30 times. Rest time is to stabilize the brain activity. In the measurement NIRS, we have started to measure brain activity of the subject becomes stable. Therefore, rest of the most first is least 5 s. It also applies to the measurement of other experiments.

Measuring Brain Activity During Transfer with Sitting Posture in an Invisible Chair (Task2). At this measurement, the subjects used welfare device to perform transferring in a sitting posture in an invisible chair. In this measurement, the subjects sat on seating face of welfare device appeared on the top of chair after raising hip until sitting posture in an invisible chair. Also, the subject performed inverse transfer from seating face to chair. Time design was rest(5 s), task(10 s) and rest(5 s). This time design was repeated 30 times.

In experiments of task1 and task2, operation of welfare device was performed by operator other than subject. Before this measuring, subjects adjusted to transferring by use of welfare device.

3 Experimental Results

3.1 Evaluation by Using NIRS

As the common result of all subjects, oxy-Hb tended to increase during task and to decrease in resting state. Therefore, it was thought that change of hemoglobin density due to task was measured. Figures 3 and 4 show trend of the channel in which significant different was shown. Analysis was performed via one-sample t-test [5–9] by a method similar to previous researches [5–9]. In this analysis, it was necessary to remove other than change of blood flow due to fatigue. So, our method was mainly focused on resting state to compare with the 1st trial and other trials of brain activity.

In task1, 1 and 2, each of sample data for analysis was 4 s after the task (Fig. 2). In the t-test of the same task, we performed t-test with first time trial and other trial which was from second times to thirty times, and examined relationship the number of trials and significant differences.

In task 1, significant different could be found from the about 10th trials. Figure 5 show the region confirmed significant difference. In task 2, significant different could be found from the about 10th trials too. Figure 6 shows region confirmed significant difference.

At first, we performed t-test using 4 s during first trial and 4 s during other trials, which were from second to fifteenth in same position.

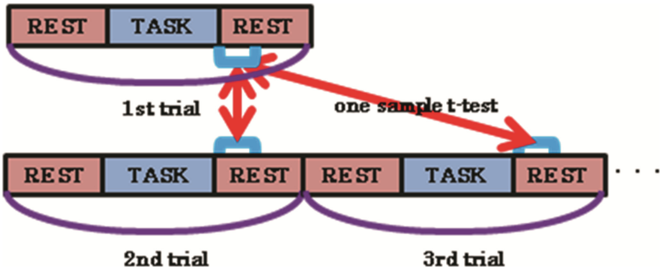

Fig. 1. T-test of sample data in task1 and 2

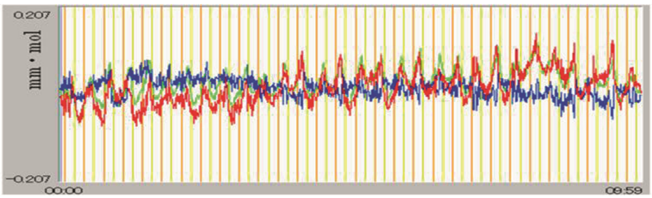

Fig. 2. Measuring result of task1

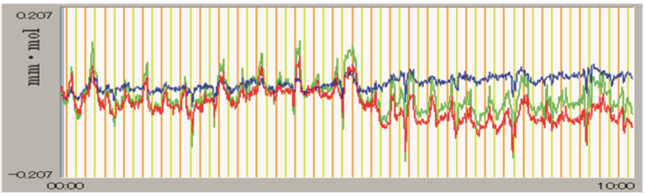

Fig. 3. Measuring result of task2

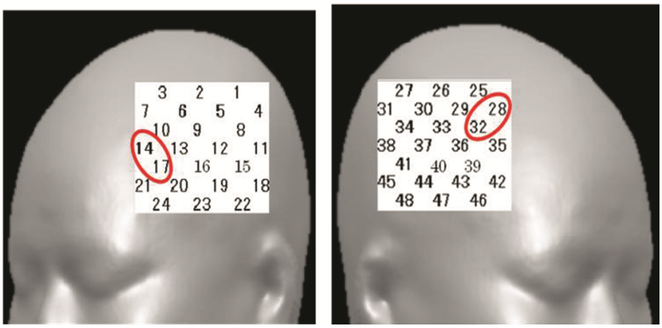

Fig. 4. Signififant difference of task1 (Color figure online)

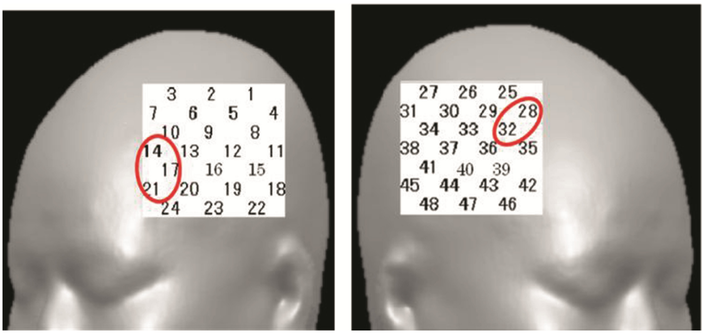

Fig. 5. Significant difference of task2 (Color figure online)

Results of Brain Activity Measurements When the Load was Applied to the Subjects. Analysis method was one-sample t-test of brain activity data as with above analysis. Figure 7 shows the result of one sample t-test between first trial of rest data and another trial of rest data. This analysis method was same with Fig. 2. Figures 8 and 9 shows the result of one sample t-test with brain activity data of different movement in the same number of trials. Red circle is the brain region that has seen a statistically significant difference in 5 of 6 subjects. Yellow circle show the brain region that has seen a statistically significant difference in 4 subjects. Green circle show the brain region that has seen a statistically significant difference in 3 subjects.

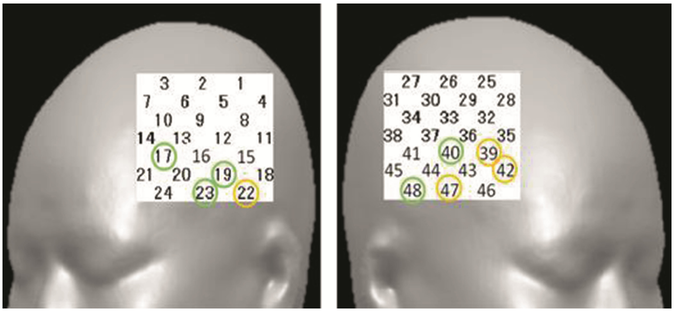

Fig. 6. Result of one sample t-test between first tial and another trials when subjects had no additional load (Color figure online)

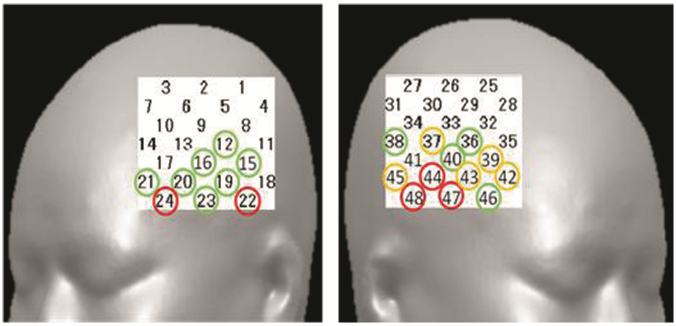

Fig. 7. Result of one sample t-test between first tial and another trials when subjects had 5 kg load (Color figure online)

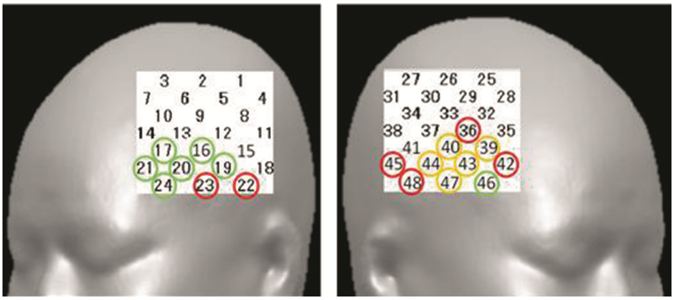

Fig. 8. Result of one sample t-test between first tial and another trials when subjects had 10 kg load (Color figure online)

In the both t-test, there were significant difference on the prefrontal cortex. These results were similar to above experiments. However, significant differences were found randomly regardless of the number of trials. As the cause of these results, there is a possibility that t-test could not remove the changes in scalp of blood flow.

t-test [5–9] by a method similar to previous researches [5–9]. In this analysis, it was necessary to remove other than change of blood flow due to fatigue. So, our method was mainly focused on resting state to compare with the 1st trial and another trials of brain activity.

In task1 1 and 2, each of sample data for analysis was 4 s after the task (Fig. 4).

In the t-test of the same task, we performed t-test with first time trial and other trial which was from second times to thirty times, and examined relationship the number of trials and statistically significant differences.

In task 1, significant different could be found from the about 10th trials. Figure 9 show region confirmed statistically significant difference.

In task 2, significant different could be found from the about 10th trials too. Figure 10 show region confirmed statistically significant difference.

Next, we performed t-test with case of standing position (task 1) and sitting posture in an invisible chair(task 2). In this analysis, significant different could be found at prefrontal area(14ch, 17ch, 28ch and 32ch). Figure 11 shows region confirmed significant different.

4 Discussion

4.1 Evaluation by Using NIRS

In this experiment, we tried to measure quantitatively the physical and psychological strain on the basis of brain activity. Also, we think that brain activity disclose human cognitive including non-verbal. As a result, it was shown that there were differences at brain activity due to number of trials and postural. In this time, analysis was performed via one-sample t-test using sample of brain activity in resting state during task or after task. Hence, analysis method was to remove disturbance such as body motion and angular variation of neck to the extent possible although there was the possibility to measure skin blood flow. Therefore, it was thought that strain due to tasks was quantitatively measured by being recognized significant differences. Also, in previous research, it was reported to decrease in activity in the brain around #10, 11 [10], as the result of measuring brain activity during Advanced Trial Making Test using PET [11]. Therefore, this result came out in support of previous research in no small part.

Results of Brain Activity Measurements When the Load was Applied to the Subjects. As a step to make the evaluation method, we performed additional experiment, which is imposed to subjects the load other than using the welfare devices. Significant difference was observed in the brain region similar to previous experiments. And, each time the load increases, brain regions found statistically significant differences became widespread. And, the frequency of showing the statistical significant difference became the higher. We think that there are the possibility of happen this results by the additional load.

Of course, it is necessary to increase number of subject at the present stage. In addition, there are problems associated with experiment, number of subject, method and measured region. However, in terms of being recognized significant differences at brain activity due to movement, it was thought to show useful result in evaluating quantitatively daily movements.

5 Conclusion

In this paper, we tried to measure physical and psychological load with measuring brain activity. And there were significant differences due to number of trials. In this experiment, analysis method was to remove disturbance such as body motion and angular variation of neck to the extent possible by using the measurement result in resting state as sample. Therefore, it was thought to show the useful result in evaluating quantitatively load due to movement task by being recognized difference in brain activity caused by number of trials.

Main purpose in this study is to evaluate physical load and fatigue quantitatively. So, we tried to evaluate change of muscle load due to difference of motion by simultaneous measuring with 3D motion analysis System and EMG quantitatively.

However, evaluation of psychological load is necessary, too. In terms of using welfare device, prolonged use must be taken into account. In this case, it is important to consider not only physical load but also psychological load due to prolonged use from standpoint of developing welfare device and keeping up surviving bodily function.

Also, in previous research, separation between physical and psychological load has been performed. But, our view is that there is correlation with physical and psychological load. So, we tried to measure psychological load including physical one based on brain activity and quantitatively evaluate both load.

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