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Analysis of cerebral blood flow in imagination of moving object

Daiki Kurematsu[a*], Hirokazu Miura[b], Noriyuki Matsuda[b], Hirokazu Taki[b]

[a]*Graduate School of Systems Engineering, Wakayama University, 930, Sakaedani, Wakayama-shi, Wakayama, 640-8441,Japan*
[b]*Faculty of Systems Engineering, Wakayama University, 930, Sakaedani, Wakayama-shi, Wakayama, 640-8441,Japan*

Abstract

We proposed operating HMD by BMI to speed up operation and to enhance the convenience in wearable device equipping HMD. But it is difficult to reflect user's thought direct on operation at this stage. In order to realize it, we need to identify a kind of human's brain signal when human thinks about moving object. So our study verifies whether it is possible to identify by imaging direction in data that we investigate cerebral blood flow changes in using NIRS when subject thinks about moving object. Identification was using neural network. The average of identification ratio of 4 direction in Total-Hb, the average of identification ratio of 4 direction in Oxy-Hb, the average of identification ratio of 4 direction in Deoxy-Hb are 32.25%, 36.0% and 37.0%, respectively. The average of identification ratio of 2 direction, up and down, in Total-Hb, the average of identification ratio of 2 direction, up and down, in Oxy-Hb, the average of identification ratio of 2 direction, up and down, in Deoxy-Hb are 63.5%, 62.0% and 62.5%, respectively. The average of identification ratio of 2 direction, left and right, in Total-Hb, the average of identification ratio of 2 direction, left and right, in Oxy-Hb, the average of identification ratio of 2 direction, left and right, in Deoxy-Hb are 58.0%, 55.5% and 69.0%, respectively. From the results, we show the possibility of identification because identification ratio are higher than chance level.

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Keywords: Brain-machine interface, Near-infrared spectroscopy, Direction identification, Neural network

* Corresponding author. *E-mail address:* s161019@center.wakayama-u.ac.jp

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1. Introduction

In recent years, by the rapid development of the brain function measurement techniques, Brain-Machine Interface (BMI) has been attracting attention which applies it, and it has been carried out a number of research. BMI is a technique which controls hardware and software by using information obtained by measuring the electrical potential or blood flow changes that occur in human brain activity. It has become active the movement to try to apply this technology in various fields. And its contributions in many field are expected, for example the medical field. The results that BMI controls the prosthetic limbs and electric wheelchairs have been reported. But, those good result often has been made by using invasive methods, because BMI needs highly accurate data. For example, subject is embedded electrode directly in the brain after craniotomy to measure data. BMI using invasive can be measured high accuracy data. However, there is possibility that lose user's health. Therefore, it is not readily available. Consequently, development of a BMI device using a non-invasive for measuring brain activity without craniotomy have been expected. And many studies have been performed. Compared with invasive, non-invasive can measure and removal easily. It is safety, because it is lower the possibility that lose user's health. Furthermore, because non-invasive measuring portable device has been developed, it is becoming enable measuring except in the medical room or a laboratory. But there is a problem that measurement accuracy falls by mixing many noise easily. So Improvement of brain activity recognition processing by data processing has become an issue. Near-InfraRed Spectroscopy (NIRS) is a one of the non-invasive type of brain function measuring device. It does not constrain body too much and is not affected by the electromagnetic waves or myoelectric.

In recent years, wearable computers that has a head mounted display (HMD) are often developed. HMD means a display device mounting on the head. There is a hat shape, a glasses shape and others. Currently, these devices are often operated by hands or voice. Therefore it have not achieved sufficient operability yet partly because some people dislike operating by voice and partly because HMD needs hands even if you operate little time. I think that if devices can be operated by thinking, these problem is solved and devices come in more useful. For example if operation can be done by think about the movement of the cursor in a menu screen, people who cannot use hands become possible to operate devices. In case of game, because if moving character by imaging we will not need controller, possibilities spread.

Using BMI to HMD, convenience is enhanced. But in the current stage, it is difficult to reflect the thinking directly in operation. In order to realize it, we need to identify a kind of human's brain signal when man thinks about moving object. Our study verifies whether it is possible to identify by imaging direction in data that we investigate cerebral blood flow changes in using NIRS when subject thinks about moving object. We experiment to measure cerebral blood flow in NIRS when subject thinks about moving object to left and right, top and bottom. We investigate a kind of characteristic and identify correlation in Interpersonal and intrapersonal when subject think about moving object to 4 direction in order to realize operating computer by humans thinking.

2. BMI studies using NIRS

Two studies related to the BMI in NIRS are shown in the following.

2.1. NIRS-based On/Off-type System for Decision-making Assist

This study considers possibility of system using brain activity of prefrontal area by developing NIRS-based on/off-type system for decision-making assist. As training task, subject memorizes any arrow, one's direction left and right, top and bottom, are displayed on the screen. After that any direction of the arrow continue to be displayed upper right on the screen at random. Then subject compares the memorized arrow with the displayed arrow and psychological state is assigned to the displayed directions accord or not. After the task completion, support vector machine learn from measured data. In maze task, subject tries to move red dot to the blue dot in the random-created maze. System displays any direction of the arrow upper right on the screen. Subject compares a direction which subject want to go with the displayed arrow and psychological state is assigned to the displayed directions accord or not. At this time system measures Oxy-Hb concentration change and identified by support vector machine. When the direction of displayed arrow accord the direction which subject want to go, red dot move to same direction.

2.2. Discrimination of subjects' intended four directions based on blood data in frontal lobe measured by 2ch NIRS

This study investigates possibility of identifying direction of the arrow by using cerebral blood flow changes which is measured by NIRS when the arrow whose direction left and right, top and bottom is displayed. Subjects equipped 2chNIRS and were measured a cerebral blood flow state of the frontal lobe. An experiment displays visual stimuli that are white cross and white arrow whose direction is left and right, top and bottom on a black background. In rest, a cross is displayed. In task, an arrow is displayed. An experiment was done in a darkroom. Stimuli of the arrow is displayed each direction ten times as 1 session, and each subject is measured 10 session. And, order of arrows displayed are at random. Subjects concentrate space on the direction of the arrow while looking the arrow.

Like NIRS-based On/Off-type System for Decision-making Assist, the way of identification that whether the direction of the arrow and the direction user wants to move accord or not is effective way because it is easy to identify. So our study try to identify signal user tries to move object for realizing quickly operation.

Like Discrimination of subjects' intended four directions based on blood data in frontal lobe measured by 2ch NIRS, if an experiment do in the darkroom, noise was decreased, and a precision of data will become better. However when BMI reality use, it will be is rare to be used in the darkroom. Therefore it is important to experiment in reality conditions and to investigate what kinds of noise are mixed. Consequently, our experiment do in open space with moderate light. If using arrow stimuli, it will become easy to identify the direction. But this way is not effective for BMI because there is possibility that user concentrates shape of an arrow. Our experiment use a black circle to make subjects do not concentrate shape. So the problem of our study is experimenting in near reality conditions and identifying a kind of direction by cerebral blood flow changes when subjects are imaging moving object.

3. Cerebral blood flow measurement experiment at the time of imagining the object movement

3.1. Experiment conditions

The number of subjects who are healthy males in their 20s is ten people. We experiment after explaining and receiving them agreement. The experiment was used wearable topography "WOT-100" made by Hitachi, Ltd. Measurement points are 10 points (7ch~16ch) with a focus on frontal lobe (figure 1).

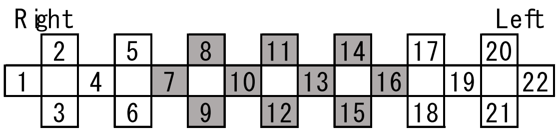

Fig. 1. Using channel

Subjects sit on the chair when experimenting. Experiment room kept a good condition by adjusting temperature, light and noise for concentrating.

3.2. The way to imagine moving object

The way to imagine moving object is to imagine immovable black circle on the display is moving. We thought The way to watch a circle moving is not suitable because subjects only watch a circle moving. In this case, there is not the mind it try to move an object. An experiment with closed eye has little noise. But our study experiments with opened eyes to meet circumstances when BMI reality use.

3.3. Experiment method

Subjects sit on the chair and gaze a frontal display. An experiment is used the block design (figure 2) as task time. In rest time, subjects gaze the cross (figure 3 right) which is on the screen without thinking about anything. In task time, subjects imagine moving the black circle (Figure 3 left) which is on the screen whose diameter is about 2 centimeters. Subjects learn the move direction that object before the experiment began. 10 task is as 1 measurement. During 1 measurement imagine all the same direction. Direction imagining is top, bottom, left and right. Each one twice.

← 7s →	← 7s →	← 7s →
Rest	Task	Rest

Fig. 2. Block design

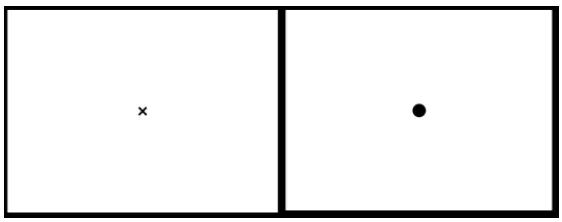

Fig. 3. Experiment image

3.4. Data processing

We processed NIRS data as follow. In the first step, we used a band-pass filter to select the data of frequencies from 0.02Hz up to 0.1Hz. In the second step, measured NIRS data of each task set is divided into 10 blocks which are included 5 seconds data before the task and 10 seconds data after the task. In the third step, we calculated baseline of measured data from 5 seconds of the beginning and the end of the task blocks, and this baseline fitting is applied to the original data. In the last step, the neural network learned the average value between task blocks of the training data and classified the test data.

3.5. Neural network

We identified the NIRS data by using hierarchical 3 layer neural network (figure 4). Input data is average of amount of hemoglobin each block, and output data is directions that is up and down, and left and right directions. Our study used data of the odd number as learning data and data of the even number as test data in neural network.

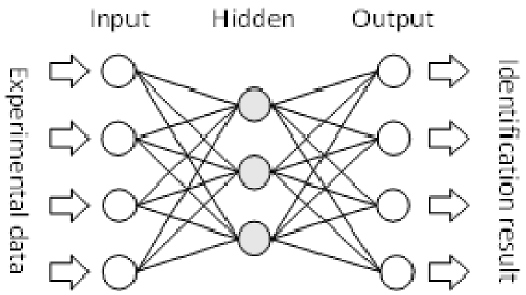

Fig. 4. Neural network

4. Experimental results

The graph that shows addition average of hemoglobin change is shown in the figure 5.

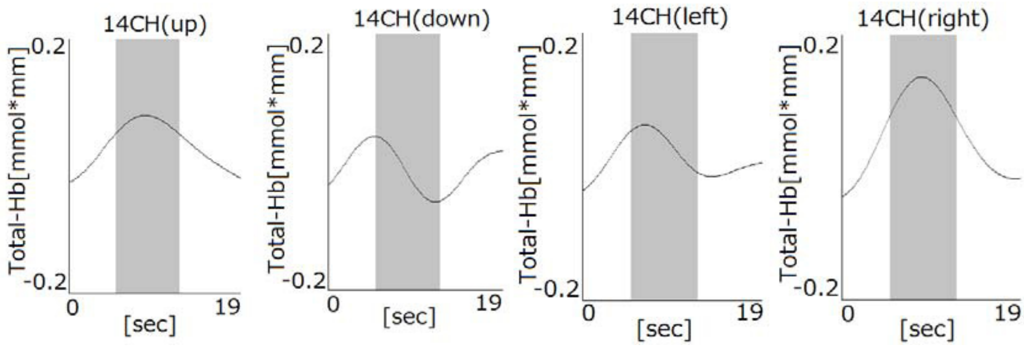

Fig. 5. Total-Hb change graph of the subject D

Figure 5 shows Total-Hb increase on the forehead when subjects imagined moving the object. In the case of Oxy-Hb and Deoxy-Hb, amount of hemoglobin changed during task time, same as Total-Hb. In rest time, the change amount of hemoglobin tended to converge 0. Thereby, we confirmed we extracted the feature we want to detect. Even if same subject imagined same direction, some waveform shown different form partly because cerebral blood flow changes is different by influence of subject's health or surrounding condition and partly because measurement instrument WOT-100 cannot fix the measurement point and a gap of measurement point may make a gap of the measurement result. Comparing waveform between each subject, timing of hemoglobin changes or amount of hemoglobin changes was different from other subject. So we can guess a cerebral blood flow change is different from individual to individual when man imagines moving object.

The identification ratio of 4 directions in neural network is shown in the table 1.

Table 1. Identification result (4 direction)

	Total-Hb					Oxy-Hb					Deoxy-Hb				
subject \ direction	up	down	left	right	average	up	down	left	right	average	up	down	left	right	average
a	30	20	40	20	27.5	40	30	20	30	30	40	40	50	60	47.5
b	40	30	20	20	27.5	40	30	30	50	37.5	60	10	30	20	30
c	40	20	30	50	35	60	20	10	30	30	70	30	30	50	45
d	40	40	20	60	40	60	30	30	50	42.5	40	20	20	50	32.5
e	50	30	20	20	30	40	30	20	40	32.5	40	30	20	30	30
f	30	30	30	20	27.5	60	20	30	30	35	40	20	20	30	27.5
g	50	30	30	40	37.5	90	40	20	30	45	90	30	20	60	50
h	50	40	20	20	32.5	60	20	30	30	35	40	20	10	30	25
i	50	40	20	20	32.5	80	30	30	30	42.5	50	0	60	40	37.5
j	50	30	30	20	32.5	40	30	10	40	30	70	20	30	60	45

Table 1 shows the average of identification ratio in Total-Hb, the average of identification ratio in Oxy-Hb, the average of identification ratio in Deoxy-Hb are 32.25%, 36.0% and 37.0%, respectively. When checking identification ratio of each direction, all type of hemoglobin is the highest identification ratio in up direction. And right direction is often the 2nd highest identification ratio. Down direction and left direction are not often high identification ratios. We guess that there are a direction which is easy to imagine and a direction which is difficult to imagine between individuals because there are a direction of high identification ratio and a direction of low identification ratio. When checking identification ratio of each subject, every average of identification ratio is more than 25%, on the other hand there are some direction whose identification ratio is lower than 25%. Deoxy-Hb is the highest the average of identification ratio, but the difference in identification ratio between individuals is large. From the above, we think Oxy-Hb is suitable input data in neural network when identifying 4 direction stably.

In addition, we identified 2 direction, up and down, and left and right. The identification ratio of 2 directions, up and down, in neural network is shown in the table 2. And the identification ratio of 2 directions, left and right, is shown in the table 3.

Table 2. Identification result (2direction up and down)

	Total-Hb			Oxy-Hb			Deoxy-Hb		
subject \ direction	up	down	average	up	down	average	up	down	average
a	60	80	70	70	60	65	50	70	60
b	50	80	65	80	80	80	50	80	65
c	60	60	60	60	50	55	60	90	75
d	50	80	65	50	70	60	30	80	55
e	60	80	70	50	60	55	30	90	60
f	40	80	60	70	50	60	60	60	60
g	80	40	60	90	30	60	60	90	75
h	60	50	55	90	70	80	80	60	70
i	70	80	75	70	70	70	40	50	45
j	50	60	55	30	40	35	50	70	60
average	58	69	63.5	66	58	62	51	74	62.5

Table 2 shows the average of identification ratio in Total-Hb, the average of identification ratio in Oxy-Hb, the average of identification ratio in Deoxy-Hb are 63.5%, 62.0% and 62.5%, respectively. When identifying the direction up or down, overall average of identification ratio in every type of hemoglobin is about the same identification ratio. When checking identification ratio of each subject, average of identification ratio is all more than 50% in case of Total-Hb. But subject j's average of identification ratio is lower than 50% in case of Oxy-Hb, and subject i's average of identification ratio is lower than 50% in case of Deoxy-Hb. From the above, we think Total-Hb is suitable input data in neural network when identifying direction up or down stably.

Table 3 shows the average of identification ratio in Total-Hb, the average of identification ratio in Oxy-Hb, the average of identification ratio in Deoxy-Hb are 58.0%, 55.5% and 69.0%, respectively. When checking identification ratio of each subject, subject e and subject j's average of identification ratio is lower than 50% in case of Total-Hb,and subject a and subject f's average of identification ratio is lower than 50% in case of Oxy-Hb, in addition subject e, subject f and subject h's average of identification ratio is lower than 50% in case of Deoxy-Hb. Comparing identification ratio in left or right with identification ratio in up or down, identification ratio in up or down is overall higher than one in up or down. Because of that, we guess that man imagines movement more easily direction vertical than direction horizontal.

Table 3. Identification result (2direction left and right)

	Total-Hb			Oxy-Hb			Deoxy-Hb		
subject \ direction	left	right	average	left	right	average	left	right	average
a	60	60	60	30	50	40	70	60	65
b	50	50	50	70	40	55	90	30	60
c	40	80	60	50	60	55	60	90	75
d	50	70	60	80	60	70	70	50	60
e	70	20	45	40	70	55	50	40	45
f	80	50	65	50	40	45	60	30	45
g	90	60	75	60	50	55	50	80	65
h	60	60	60	60	50	55	30	50	40
i	70	50	60	70	50	60	80	60	70
j	60	30	45	60	70	65	80	50	65
average	63	53	58	57	54	55.5	64	54	59

5. Conclusion

We proposed operating HMD by BMI to speed up operation and to enhance the convenience in wearable device equipping HMD. But it is difficult to reflect user's thought direct on operation at this stage. In order to realize it, we need to identify a kind of human's brain signal when man thinks about moving object. So our study verifies whether it is possible to identify by imaging direction in data that we investigate cerebral blood flow changes in using NIRS when subject thinks about moving object. Identification was using neural network. The average of identification ratio of 4 direction in Total-Hb, the average of identification ratio of 4 direction in Oxy-Hb, the average of identification ratio of 4 direction in Deoxy-Hb are 32.25%, 36.0% and 37.0%, respectively. The average of identification ratio of 2 direction, up and down, in Total-Hb, the average of identification ratio of 2 direction, up and down, in Oxy-Hb, the average of identification ratio of 2 direction, up and down, in Deoxy-Hb are 63.5%, 62.0% and 62.5%, respectively. The average of identification ratio of 2 direction, left and right, in Total-Hb, the average of identification ratio of 2 direction, left and right, in Oxy-Hb, the average of identification ratio of 2 direction, left and right, in Deoxy-Hb are 58.0%, 55.5% and 69.0%, respectively. From the results, we show the possibility of identification because identification ratio are higher than chance level.

In the future, In the future, to improve identification ratio, we will check identification ratio each channel and choose channel to identify, and we will experiment in several task length.

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References

1. R.Hasegawa. Development and Future of Brain-Machine Interface. *The Journal of the Institute of Electronics*; 2008. Vol.91. No.12. pp. 1066-1075.
2. H.Wtanabe, K.Lee, H.Sakamoto, K.Tanaka, H.Ohtake. Electroencephalogram-based control of an electric wheelchair. *Proceedings of the 2008 JSME Conference on Robotics and Mechatronics*; 2008.
3. T.Yamanoi, H.Toyoshima, T.Yamazaki, M.Sugeno. Micro-Robot Control by Use of EEG on Imaging Arrows. *Japan Society for Fuzzy Theory and Intelligent Informatics*; 2008. Vol.24. No.0. pp. 43-43.
4. H.Toyoshima, T.Yamanoi, T.Yamazaki, S.Ohnishi, M.Sugeno. Comparison of Spatiotemporal Activities in Human Brain for Words and Symbols with Directional Meaning. *Journal of Japan Society for Fuzzy Theory and Intelligent Informatics*; 2006. Vol.18. No.3. pp. 425-433.
5. S.Kanoh, S.Reinhold, T.Yoshinobu, N.Hoshimiya, P.Gert. A Basic Study on Brain-Computer Interface to Detect Foot Movement Imagery from EEG. *IEICE Technical Report*; 2006. Vol.106. No.370. pp. 9-12.
6. K.Gotho, S.Takano, T.Nisawa, S.Hirobayashi. NIRS-based On/Off-type System for Decision-making Assist. *Transactions of the Japanese Society for Artificial Intelligence*; 2011. Vol.25. pp. 1-4.
7. R.Nagayama, M.Kikuchi. Discrimination of subjects' intended four directions based on blood data in frontal lobe measured by 2ch NIRS. *ITE Techinical Report*; 2014. Vol.38. No.10. pp. 29-32.
8. N.Baba. Fundamental Theories of Networks and Various Applications. *ISCIE Journal 'Systems, Control and Information*; 2009. Vol.53. No.5. pp. 197-204.