A Comparative Study of Brain Activities Engaged in Interface Operations by Means of NIRS Trajectory Map

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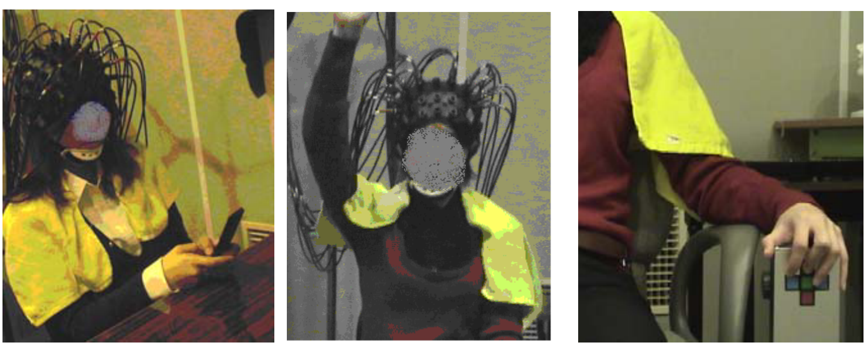
Abstract. This paper studies an elemental human action, hand up-down, and selective button operations, by means of NIRS. In the analysis, we pay attention to NIRS trajectory and the total Hb changes. Our results provided empirical support for the hypothesis that the trajectory of positive inclination indicates brain location actively contributing the task, and negative inclination is the brain locations out of contribution. The locations positively contributing to the task are found most intensively in right and left forebrain area but in middle part of left brain looks less contributing to the task.

Keywords: NIRS, hand up-down, button selection, trajectory, brain map.

1 Introduction

The attempt to apply NIRS to brain activities started to analyze text entry behaviors to mobile phone [1]. The studies are continuing to some of more elemental human actions, like hand up-down, finger shaping, finger matching and, again to actions realistic to human interface, a single button press, and selective button operations.



a) mobilephone b) hand up-down c) button selective operation

Fig. 1. Behaviors under experiment by using NIRS

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In this paper, experimental finding on hand up-down action and on button selective operation are reported.

2 Experimental Systems

NIRS (Near Infra-Red Spectroscopy) facility was a product of Shimadzu co. (OMM3000/12) which is installed in Future ITC Research Center, KARC (Kansai Advanced ICT Research Center, Akashi, Kobe, Japan). The experimenters are honored by Joint Research Treaty with the center to use the NIRS facility. The NIRS had 12 light transmitter and receiver pairs and was capable of processing up to 54 channels of brain activities depending on transmitter and receiver arraignment. The arraignment we adopted in measurement is shown in Fig. 2,

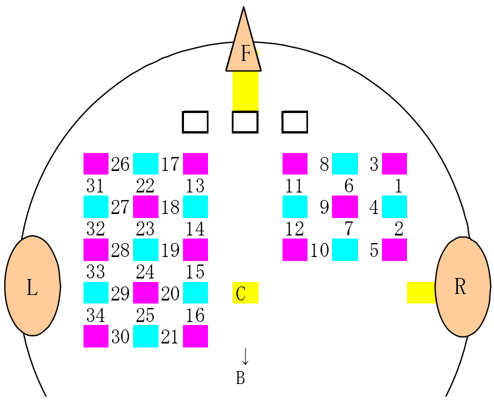


Fig. 2. Transmitter/receiver arraignment

By this arraignment, 34channel brain activities are collected every 0.1second. Beside NIRS data, the machine is capable of 8 external analogue signals, which are used to record start, stop and task completion signals together with NIRS data. The above arraignment was chosen since forehead brain activities are more important to human interface activities and that left brain activities seemed more complex based on preliminary NIRS studies.

Experimental task design and the analysis methods are developed by authors. At this moment, the subject participated in the measurement is graduate student, volunteered with informed consent in accordance with the Institutional Review Board of Kobe Women's University. The purpose of this paper is to show possibilities of NIRS trajectory and the trajectory map from the methodological aspect. Analysis for larger population should be reported elsewhere.

In the previous paper [2], NIRS trajectory and trajectory map are illustrated on one person, one trial base, although they are representing mostly common features of brain activities under similar situations. The analysis in this paper is the attempt to apply the method to multiple trials and take event wise average for equivalent data.

Two experiments in this paper are to examine brain activities related to select hands and fingers proper to the task.

2.1 Hand Selection Task (Hands Up-Down)

Subject sat on a chair with her hands on the knee. Experimenter gave an instruction in a random order, which hand (left, right, both) to raise at the next trial. The subject raised her hand to upright position following a auditory tone. With 2 seconds of time subject raised her hand to the upright position and back to knee position. The hand remained on the knee position another 2 seconds and waited for next instruction.

Two sequences of 9 trials are applied. NIRS data after start tone signal were collected sidewise (left, right, both).

2.2 Finger Selection Task (Button Selection)

Subject rest her hand (left or right) on the button box. Computer generated voice give instruction to choose right, left or up, down button. The subject fingers are allocated at home position, in which middle finger stay in the location of square in the Fig. 3. In case of left or right instruction, index or ring finger is selected depending on the hand in use. In case of up or down instruction, middle finger has to change its location by changing the bending angle. The change in necessary action might be related to different brain activities to be analyzed in this paper.

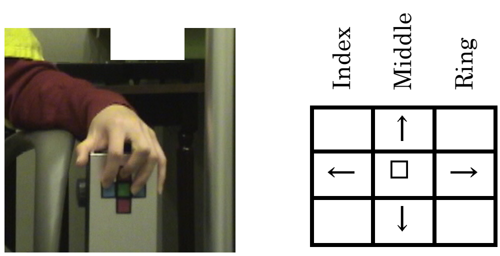


Fig. 3. Button box operated by left hand (photo), and the direction and finger allocation

3 Results

3.1 Hand Selection

NIRS data are zero adjusted at the beginning of each trial, and data from 6 same trials are averaged. Using averaged data of each channel, average NIRS trajectory is drawn. The NIRS trajectory in this case is always starting from the origin of the graph. Average NIRS trajectory for each channel is shown in 34 cells of Fig. 4, where right brain channels are in the right, and the left brain in the left side of the figure. The

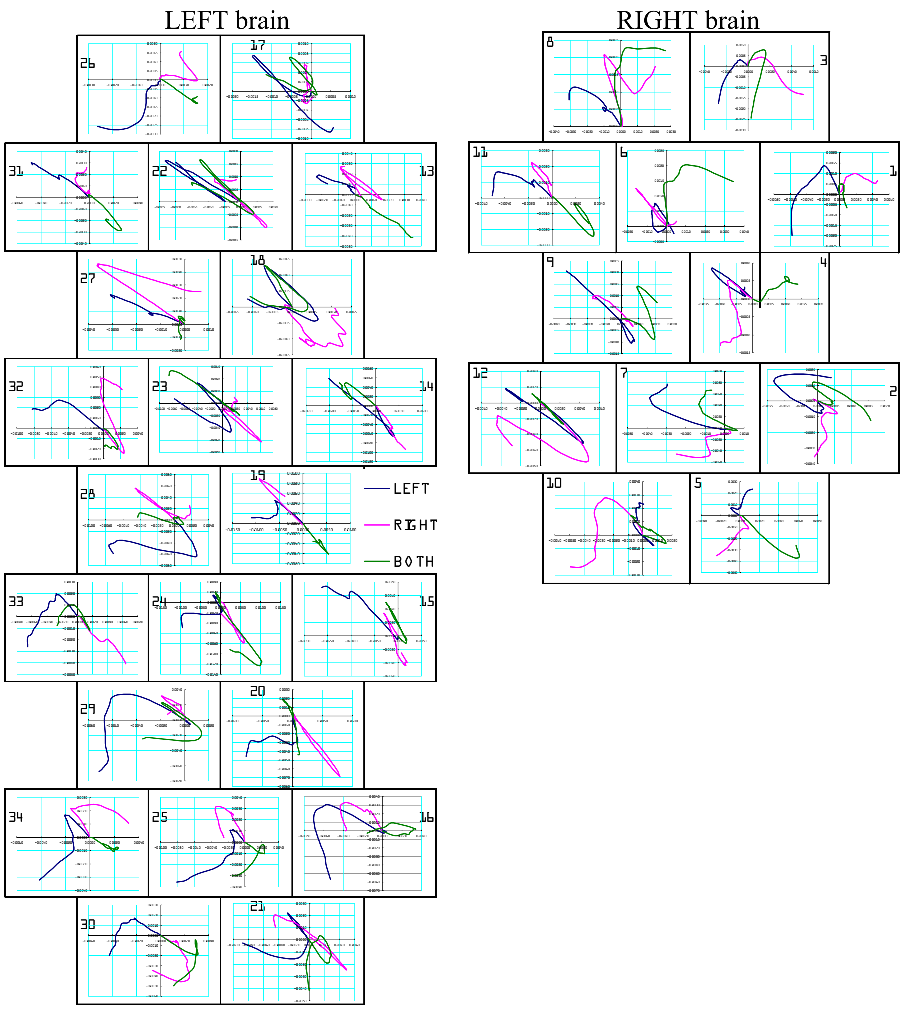


Fig. 4. The brain map of average NIRS trajectory for hand up-down

channel number is indicated in each cell. The blue plot is for the left hand, the red for the right, and the green for the both hands.

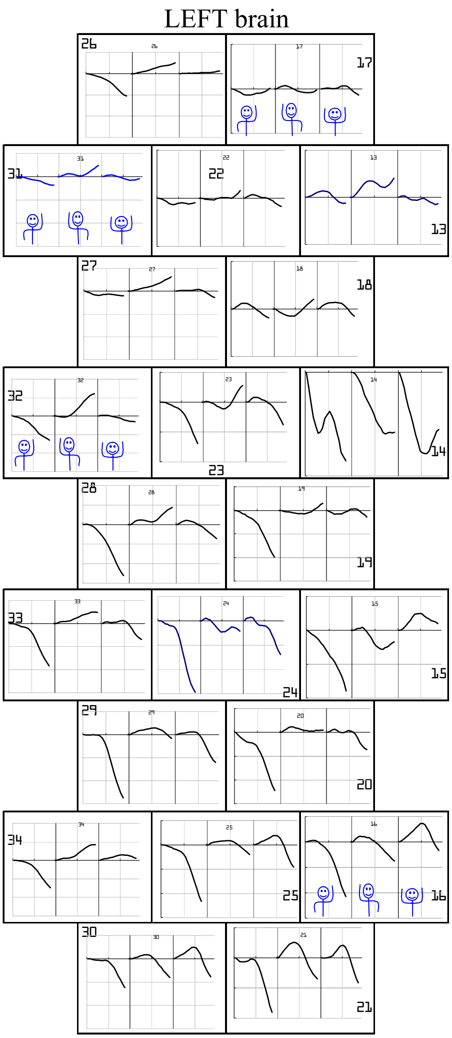
If the average trajectory is along -1 inclination line, the total Hb change is slow. If the average trajectory is leaving the origin along +1 inclination, the total Hb change is quick. Our tentative assumption is trajectory of positive inclination indicates brain location actively contributing the task, and negative inclination is the brain locations not contributing the task.

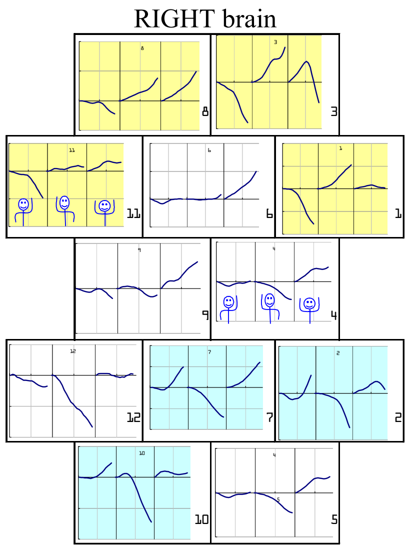
The locations positively contributing to the task are found most intensively in right and left forebrain area but in middle part of left brain looks less contributing to the task.

Each point of NIRS trajectory is corresponding to total Hb value but it does not correspond to the time course of total Hb. For the understanding of physical events, time course is also essential. Average time course of total Hb for each channel is shown in Fig. 5.
Channel 12 shows exceptional change.

In the left brain, most channels shows decrease to left hand-up action, but to the right and the both hand-up, the response is different from channel to channel. The functions of each brain area might be different from channel to channel.

It is interesting that the functional differences of left and right forebrain are confirmed by NIRS measurement.





Each cell in this figure corresponds to a NIRS channel. Three sub cells in a cell are showing total Hb change to Left, Right and Both hand-up action, from left to right respectively.

Total Hb changes of right brain are regular in the right brain. In the front two rows, total Hb decreases to left hand-up, increases to right hand-up, and increases to both hand-up. To the contrary, in the channels behind third row, total Hb increases to the left hand-up, and decreases to the right hand-up.

Fig. 5. Average time course of total Hb to hand-up actions

3.2 Finger Selection

NIRS is a relative measuring system. Thus normally at each starting point of trials, the zero adjustment is done. It is also possible to apply the adjustment at each goal point and analyze the data shortly before and after the zero. For the Finger selection trials goal based analysis is introduced. One half of a second before and after the goal point is analyzed.

One set of data of 6 trials taken from a channel is shown in Fig. 6. Fig. 6a is for the case operator pushed the Left direction button with ring finger of Left hand. The action is indicated by LD(ring/LH). Three other actions are indicated in Fig. 6. For each action, 10 trials are included in two sequences of experiment.

Each time course of total Hb change has considerable variation, the average are taken to each cases of each channel. Four average data of 10 channels are shown in Fig. 7 a, b. These channels are selected from 34 channels covering left and right brain.

Some variations among channels can be notified by visual observations. To get quantitative evaluations, correlation analyses are applied to the average data. Since our actions under consideration are four, total 16 correlations are to be considered. But 4 correlations are always 1 (cross hatched in Table 1), and 6 correlations are symmetric to rest of 6 (single hatched). Resultantly, 6 correlations are interesting to study. Criteria to evaluate correlation are set as follows:

- strong (positive, negative) : p >= 0.8, p =< -0.8
- fair (positive, negative) : > 0.8 > p >= 0.5, -0.5 =< p < -0.8
- low : -0.5 < p < 0.5

Based on the above criteria, strong and fair correlation data are shown in Fig. 7.

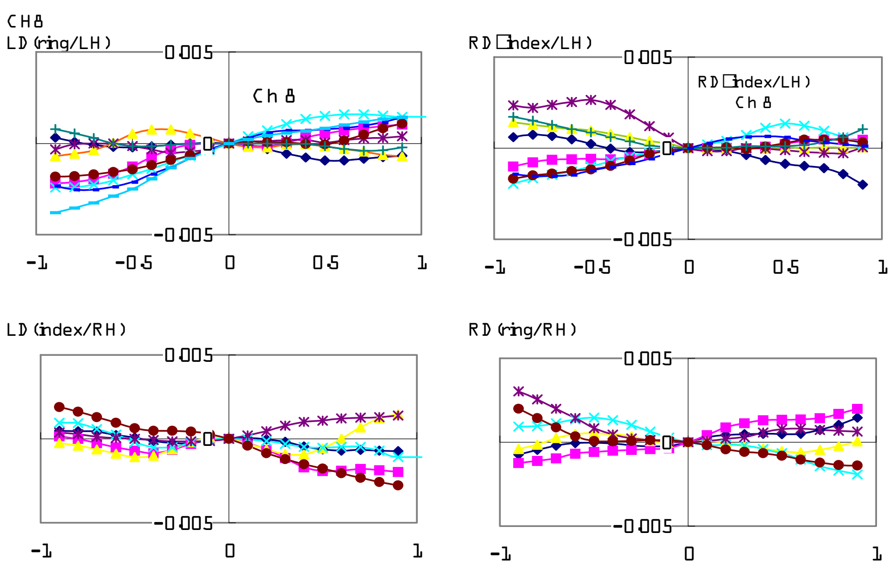


Fig. 6. Total Hb change around the goal (individual responses)

Table 1. Correlations to be considered

	LD(ring/LH)	RD(index/LH)	LD(index/RH)	RD(ring/RH)
RD(ring/RH)	(1)	(2)	(3)	
LD(index/RH)	(4)	(5)		
RD(index/LH)	(6)			
LD(ring/LH)				

If correlations are strong (near +1), or inversely (near -1) correlation in the cells (1)~(6), following remarks can be made:

Selectivity	description
(1) finger	same finger (ring) of different hand to the different direction
(2) direction	same direction by different finger of different hand
(3) hand	different finger of same hand toward different direction
(4) direction	same direction by different finger of different hand
(5) finger	same finger (index) of different hand to the different direction
(6) hand	different finger of same hand toward different direction

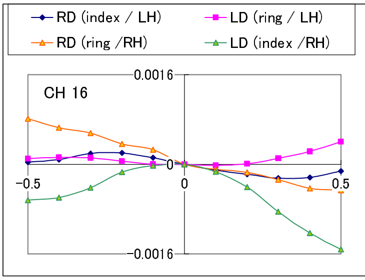
Functional features of each channel in Fig. 7 might be described below.

1: negative correlation between index and ring finger of left hand
3: positive correlation to same direction, negative correlation to different direction.
8: strong negative correlation to the same finger of different hand.
10: negative correlation to different direction, strong correlation to same direction
12: strong positive or negative correlations to every action.

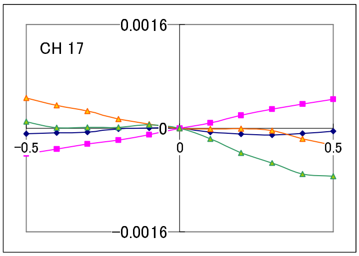
16: negative correlation to left, positive correlation to right.
17: strong correlations to fingers of different and same hands
26: high negative correlation to same hand different finger operation.
31: strong correlation to fingers of same and different hands
34: strong correlation to same direction operation

The above are preliminary observation of limited channels. Further results will be explained at the session. Data are also collected from middle finger in this experiment. An action of middle finger is different from index and ring, in that the finger makes constriction and extension to make proper tap. Studies of the data will be reported otherwise.

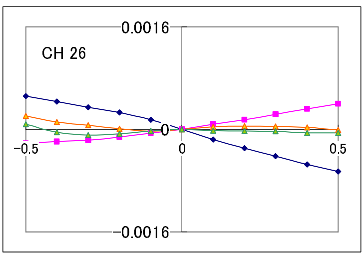
Further studies are also in preparation. People operate key box not only from orthodox position. Especially for mobile devices, heterodox operations are often noticed. But heterodox operation sometime induces miss operation or unexpected results. Preventing human error at the brain level might be most basic importance in human interface studies.



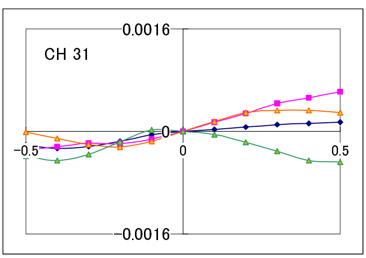
CH 16	LD(ring / LH)	RD(index/ LH)	LD(index / RH)
RD(ring / RH)		**0.81**	
LD(index/ RH)	-0.93	0.55	
RD(index / LH)			



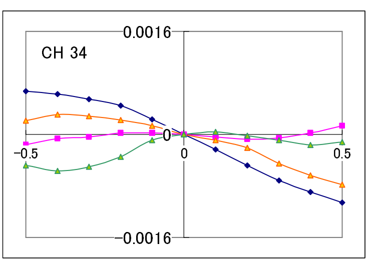
CH 17	LD(ring / LH)	RD(index/ LH)	LD(index / RH)
RD(ring / RH)	-0.95		**0.81**
LD(index/ RH)	-0.93		
RD(index / LH)			



CH 26	LD(ring / LH)	RD(index/ LH)	LD(index / RH)
RD(ring / RH)		0.53	0.60
LD(index/ RH)			
RD(index / LH)	-1.00		



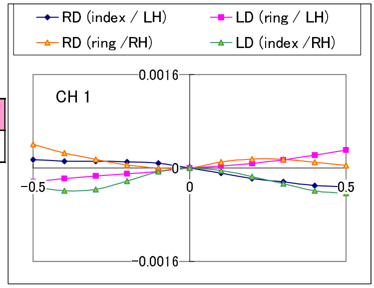
CH31	LD(ring / LH)	RD(index/ LH)	LD(index / RH)
RD(ring / RH)	**0.91**	**0.86**	
LD(index/ RH)			
RD(index / LH)	**0.93**		



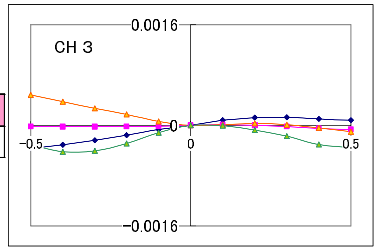
CH34	LD(ring / LH)	RD(index/ LH)	LD(index / RH)
RD(ring / RH)	-0.54	**0.98**	-0.58
LD(index/ RH)		-0.69	
RD(index / LH)	-0.53		

Fig. 7 a). Average total Hb and the correlation for finger selections (left brain)

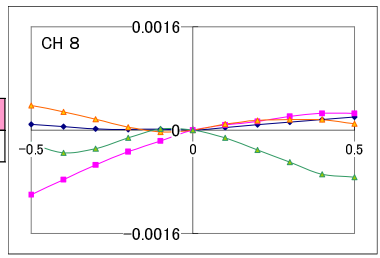
CH1	LD(ring / LH)	RD(index / LH)	LD(index / RH)
RD(ring / RH)	-0.52		
LD(index / RH)			
RD(index / LH)	-0.97		



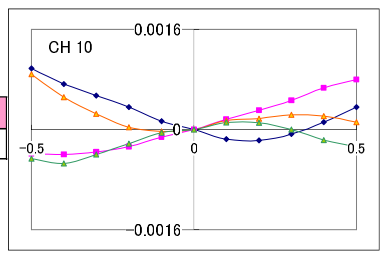
CH 3	LD(ring / LH)	RD(index/ LH)	LD(index / RH)
RD(ring / RH)	-0.90	**0.79**	-0.50
LD(index/ RH)			
RD(index / LH)	-0.95		



CH 8	LD(ring / LH)	RD(index/ LH)	LD(index / RH)
RD(ring / RH)	-0.61		
LD(index/ RH)		-0.92	
RD(index / LH)			



CH 10	LD(ring / LH)	RD(index/ LH)	LD(index / RH)
RD(ring / RH)		**0.74**	-0.66
LD(index/ RH)		-0.96	
RD(index / LH)	-0.58		



CH 12	LD(ring / LH)	RD(index/ LH)	LD(index / RH)
RD(ring / RH)	-0.95	**0.92**	**0.94**
LD(index/ RH)	-0.87	**0.96**	
RD(index / LH)	-0.85		

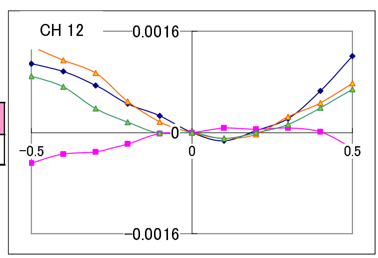


Fig. 7 b). Average total Hb and the correlation for finger selections (right brain)

4 Conclusions

Previously NIRS trajectory is introduced [1], and the trajectory map [2, 3] was proposed to show brain activities performing a task, by allocating trajectories of different part of the brain. Trajectory map study has suggested, the right forebrain is taking more role in some tasks like text entry to mobile phone. And the functional asymmetry forebrain is distinct. NIRS trajectory method and trajectory map are applied to legibility study [4, 5].

Brain function asymmetry is again confirmed in the hand up-down experiment. Finger selection experiments [6, 7] are expected to reveal further knowledge on the brain functional allocation. Past PET studies on tapping are also suggestive to this study.

NIRS measurement will be an essential study tool for human interface.

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