Hemodynamic Changes in the Prefrontal Cortex in Smooth and Non-smooth Performance Measured by Near-Infrared Spectroscopy (NIRS)

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Keywords: attentional demand, mirror drawing, prefrontal cortex, near-infrared spectroscopy

Introduction

Prefrontal cortex is active during new learning of a skill but not active during automatic performance of a learned skill (Jueptner, et al., 1997). Rowe, et al. (2002) showed attention to action increased activity in prefrontal cortex. These results seem to indicate that attention is required early in skill learning, but that attention demands decrease as a person becomes more skilled. Previous studies used sequential movements. In this study, we used computerized mirror drawing task measured by near-infrared spectroscopy to allow our participants relatively free and natural movements. We could also identify the different performance types, specifically, smooth and skilled performance and non-smooth and less skilled performance and clarify the relations between performance types and the activation of the prefrontal cortex.

Method

Participants

The participants were 9 healthy volunteers (age range 23-25). They are all right-handed.

Procedure

The participants were asked to control a joystick by their right hand to trace a mirror image of a star-shape (about 12 cm width on the computer monitor) that was drawn by two lines of an inner, smaller star and a surrounding larger star. They were asked to trace the star without touching or crossing the two lines that were 7 mm apart. International 10-20 System was used to determine Fz and overall position of the probes were set in such a way that the activation of the prefrontal cortex could be investigated in each hemisphere. Changes in the concentration of oxy-, deoxy-Hb, and total Hb (sum of oxy- and deoxy-Hb) were measured by near-infrared spectroscopy (NIRS, ETG-4000 system, Hitachi Medical Corporation, Tokyo, Japan)

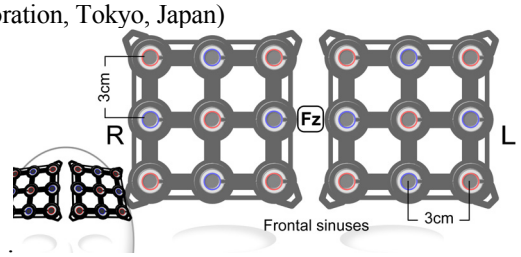

Figure 1. Probe set up

There were 4 sets of 40 seconds of mirror drawing task and 80 seconds of rest and 10 seconds of baseline periods.

Results and Discussion

We calculated the Z-scores of oxy-Hb and total-Hb for each channel within a participant. We defined the participant did a smooth performance without hesitation if he continuously manipulated the joystick for 0.5 s or more. A continuous manipulation of less than 0.5 s was a performance with hesitation. If the participant drew a line in the appropriate course for 1 or more than 1 s, it was an "on-course" performance. For 1 or less than 1 s, it was an "off-course" performance. The tracing time of on-course performance increased while off-course performance decreased as the participant repeated the task. The Table 1 shows the number of more activated channels compared with baseline and the means of the Z-scores of oxy-Hb and total-Hb. It was found that 1) in the performance type of on-course with hesitation, fewer channels of prefrontal cortex were activated relative to other performance types, and these channels were activated only in the last two trials. Attention demands in this performance may be different from those of other performance types, 2) activation generally decreased in other performance types, and this decrease seemed to be more evident in the right hemisphere.

Table 1. The total number of activated channels and means of Z-scores in different performance types

		Left		Right	
Performance type	Trial	Number of chs.	Mean	Number of chs.	Mean
On-course w/o hesi.	1st-2nd	4	1.582	5	1.387
	3rd-4th	2	1.259	2	0.983
On-course wi hesi.	1st-2nd	0	n/a	0	n/a
	3rd-4th	2	1.375	1	1.183
Off-course w/o hesi.	1st-2nd	4	2.421	4	2.145
	3rd-4th	3	1.749	2	1.615
Off-course wi hesi.	1st-2nd	4	2.178	4	2.015
	3rd-4th	4	1.813	1	1.105

Acknowledgments

This study was supported by the 21st Century Center of Excellence Program "Human Adaptive Mechatronics," at Tokyo Denki University.

References

Jueptner, M., K. M. Stephan, C. D. Frith, D. J. Brooks, R.S.J. Frackowiak, and R. E. Passingham. Anatomy of motor learning. I. Frontal cortex and attention to action. J. Neurophysiol. 77: 1313-1324, 1997.

Rowe J, Frackowiak RSJ, Friston K, Passingham RE. Attention to action: specific modulation of cortico-cortical interactions in humans. NeuroImage 17, 988-998, 2002.