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ARTICLE

Cerebral haemodynamics during motor imagery of self-feeding with chopsticks: differences between dominant and non-dominant hand

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ABSTRACT

Purpose: Motor imagery is defined as a dynamic state during which a subject mentally simulates a given action without overt movements. Our aim was to use near-infrared spectroscopy to investigate differences in cerebral haemodynamics during motor imagery of self-feeding with chopsticks using the dominant or non-dominant hand.

Materials and methods: Twenty healthy right-handed people participated in this study. The motor imagery task involved eating sliced cucumber pickles using chopsticks with the dominant (right) or non-dominant (left) hand. Activation of regions of interest (pre-supplementary motor area, supplementary motor area, pre-motor area, pre-frontal cortex, and sensorimotor cortex was assessed.

Results: Motor imagery vividness of the dominant hand tended to be significantly higher than that of the non-dominant hand. The time of peak oxygenated haemoglobin was significantly earlier in the right pre-frontal cortex than in the supplementary motor area and left pre-motor area. Haemodynamic correlations were detected in more regions of interest during dominant-hand motor imagery than during non-dominant-hand motor imagery.

Conclusions: Haemodynamics might be affected by differences in motor imagery vividness caused by variations in motor manipulation.

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KEYWORDS
Imagery (psychotherapy); haemodynamics; motor cortex; spectroscopy near-infrared; rehabilitation; mental practice

Introduction

Motor imagery (MI) can be defined as a dynamic state during which a subject mentally simulates a given action without any overt movements (Decety 1996; Blefari et al. 2015). With advances in neuroimaging systems, cortical activation during MI tasks can now be measured. For example, in a near-infrared spectroscopy (NIRS) study, both motor execution (ME) and MI of hand-finger opposition tasks increased cerebral blood flow in almost all of the same areas, including the prefrontal cortex (PFC), primary motor cortex, and sensorimotor cortex (SMC) (Wriessnegger et al. 2008). Also, in a transcranial magnetic stimulation study, the motor-evoked potential, which is indicative of cortico-spinal excitability, was significantly larger during MI than during rest (Roosink and Zijdewind 2010; Feurra et al. 2011). Moreover, a previous functional magnetic resonance imaging study suggested that nearly the same cerebellar areas are activated during ME and MI of activities that require the use of tools, despite the activation differences among tasks (Higuchi et al. 2007).

Many studies have investigated cerebral activation during MI of simple tasks, but only a few have focussed on MI of complex tasks, such as activities of daily living (ADLs), which are relevant clinically. Some ADLs are impacted by handedness. For example, self-feeding with chopsticks requires several types of movement, such as arm and finger movements, and the use of tools, which are difficult to execute with the non-dominant hand. Thus, if the MI ability is also affected by handedness, the haemodynamics during MI of self-feeding with chopsticks might be different between the dominant and non-dominant hand. Additionally, MI vividness might also differ between hands; indeed, previous studies have suggested that cerebral activity can differ according to MI vividness (Williams et al. 2012).

Hence, our hypotheses were as follows: there would be differences in (1) cerebral haemodynamics and (2) MI vividness during MI of self-feeding with chopsticks between the dominant and non-dominant hand. Thus, our aim was to use NIRS to investigate differences in cerebral haemodynamics during MI of self-feeding with chopsticks using the dominant or non-dominant hand. Our findings provide basic knowledge for the use of MI in ADLs in clinical scenarios.

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Supplemental data for this article can be accessed here.

Materials and methods

Subjects

Twenty healthy right-handed participants (14 women, 6 men; age: 26.9 ± 8.8 years) participated in this study. All participants were consistent right-handers according to the Edinburgh handedness inventory (Oldfield 1971). After being informed about the safety regulations for the study and acknowledging that they cannot be identified through this manuscript, all participants provided written informed consent for participation. No participants had a history of neurological illness, head injury, major physical illness, or psychiatric disorders. This study was conducted in the Biomedical Science Department of Nagasaki University. It was approved by the Nagasaki University ethical review committee and complied with the Declaration of Helsinki (World Medical Association 2001).

MI Task

The MI task required that the participant imagine he or she is eating sliced cucumber pickles using chopsticks, including chopstick manipulation, bringing the pickle into the mouth, chewing, and swallowing. MI was performed in two conditions: one was MI with the dominant hand (dominant MI), and the other was MI with the non-dominant hand (non-dominant MI).

To decrease the variability in MI between participants, all participants completed a 5-min MI practice session with practice videos (Figure 1) before each task (S1A and S1B Video). The practice video represented the first-person view, which showed that the sliced cucumber pickles were in a dish on a table; the person picked up a pickle with the chopsticks and brought it to the mouth. The video was accompanied by the sound of pickles being eaten, which could be heard through earphones. The practice video length (from chopsticks manipulation to swallowing) was 10 s, which was the same as the length of the actual MI task. To ensure consistency between practice videos for the right and left hands, the video for the MI condition using the non-dominant hand was created by inverting the video of the dominant hand.

Experimental protocol

The participants sat on a comfortable chair in a quiet room. They were instructed to put their forearms in an intermediate position on the table, to relax, not to move their head or arms as much as possible, and not to speak during the experiment. After showing the MI practice videos, NIRS measurements were collected as part of a block design, which included three cycles of 20 s of the task and 30 s of rest (Figure 2), as in a previous study (Iso et al. 2016). This block design was consistent between the two conditions, comprising three cycles of the task (total 6 trials) in the dominant MI condition and another three cycles of the task (total 6 trials) in the non-dominant MI condition. All participants were examined in both conditions.

The condition order (dominant MI and non-dominant MI) was counter-balanced. The participants were asked to imagine eating pickles twice for 20 s and to imagine that they were actually doing it. Thus, they imagined kinaesthetic imagery, which included sounds, and were instructed not to move and to keep their eyes closed. Participants were instructed to maintain the same position and to relax

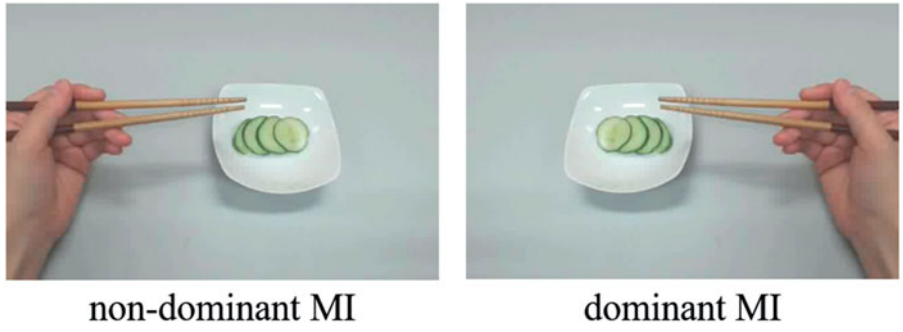

Figure 1. Still image of the MI practice video. The video represents the first-person view. One practice cycle (from chopstick manipulation to swallowing) was 10-s long, which was the same length as the actual MI task. The video for the non-dominant MI condition was created by inverting the dominant MI condition video. MI: motor imagery.

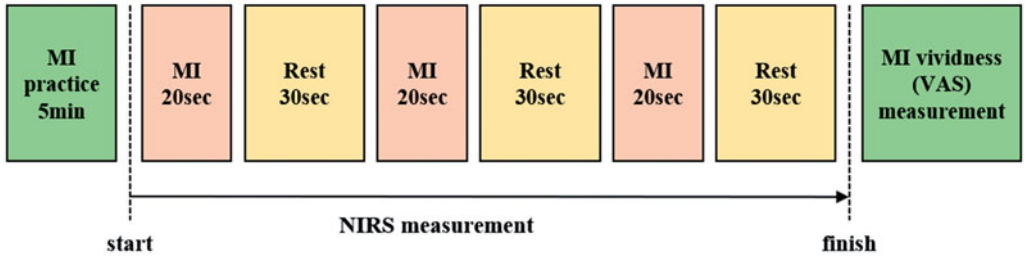

Figure 2. Experimental protocol. NIRS measurements were collected as part of a block design, which included three cycles of 20 s for the task and 30 s of rest. The 5-min MI practice session was completed before NIRS measurements were obtained, and MI vividness was measured by the VAS following the NIRS measurements. MI: motor imagery; NIRS: near-infrared spectroscopy; VAS: visual analogue scale.

without thinking during the rest period. They were notified when the task or rest session began by the words "start" or "stop," announced by the researcher.

The visual analogue scale (VAS), which is used to assess subjective MI vividness (Lotze et al. 2003; Lotze and Halsband 2006; Malouin et al. 2008; Ikeda et al. 2012), was employed to investigate MI vividness after each MI task. The participants were asked how vividly they could imagine the MI task and were instructed to mark their responses on the VAS, which ranged from 0 mm (0%; none) to 100 mm (100%; very vivid).

NIRS measurements

NIRS is non-invasive and easy to use, and its reliability and replicability have been demonstrated previously (Kono et al. 2007; Maslehaty et al. 2012; Iso et al. 2016). It can detect changes of cerebral oxygenation while subjects are performing tasks, even in clinical scenarios. In this study, changes in oxygenated haemoglobin (oxy-Hb), deoxygenated haemoglobin (deoxy-Hb), and total haemoglobin levels were recorded using the ETG-4000 system (Hitachi Medical Co., Tokyo, Japan) with 24 channels, which consisted of 4×4 optode probe sets (8 emitters and 8 detectors). Each probe was placed 3.0 cm away from the other probes. The NIRS channels were positioned according to the international 10–20 electroencephalography placement system (Okamoto et al. 2004), and Cz was positioned as a replicable marker of the probes, as determined by previous studies (Figure 3) (Okamoto et al. 2004; Saimpont et al. 2016). The present system used two wavelengths of near-infrared light, which were approximately 625 and 830 nm, and the reflected light was sampled at 10 Hz. This system estimates changes in oxy-Hb levels at a depth of 3.0 cm below the scalp.

Activation of the pre-supplementary motor area (PreSMA), supplementary motor area (SMA), bilateral PFC, bilateral premotor area (PMA), and bilateral SMC were assessed as the regions of interest in this study (Figure 3). The activity level of the PreSMA was detected by channels 2, 5, and 6; that of the SMA by channels 9, 12, 13, and 16; of the left PFC (L-PFC) by channels 1 and 4; and of the right PFC (R-PFC) by channels 3 and 7. Moreover, the activity level of the left PMA (L-PMA) was detected by channels 8, 11, and 15; that of the right PMA (R-PMA) by channels 10, 14, and 17; of the left SMC (L-SMC) by channels 18 and 22; and of the right SMC (R-SMC) by channels 21 and 24 (Hatakenaka et al. 2007; Sagari et al. 2015; Iso et al. 2016).

The detected haemoglobin levels were converted to changes in oxy-Hb and deoxy-Hb levels based on the modified Beer–Lambert approach (Cope and Delpy 1988; Obrig and Villringer 2003). In this study, we used the mean oxy-Hb concentration changes and peak oxy-Hb timing to signify brain activation caused by the MI task, as oxy-Hb levels represent a sensitive parameter to detect brain activation (Hoshi et al. 2001). The moving average method (window: 5.0 s) was used to remove short-term motion artefacts from the analysed data. The obtained data were analysed using the integral mode, which calculates the average waveform from three cycles of data acquisition. We determined the pre-task baseline as the mean over the 5.0 s prior to the task period, and the post-task baseline as the mean over the last 5.0 s of the post-task period. We applied linear fitting to the data between these two baselines. The first 5.0 s of each task were excluded from the analyses to ensure that the data would not affected by the nerve–blood vessel coupling system, a phenomenon in which brain blood vessel ectasia and increased brain blood flow require time to occur. Thus, the last 5.0–20.0 s (total: 15.0 s) of the task period were used for analyses (Figure 4), and all data for the three cycles were calculated using the signal-averaging technique. Channels with high noise levels were marked using a high-pass filter at 3.0 Hz, which was 0.1 standard deviation above the wave analysis, so that it would not be affected by noise or hyperactivation due to skin blood flow (Takahashi et al. 2011). The mean, peak time, and standard deviation were examined for all participants.

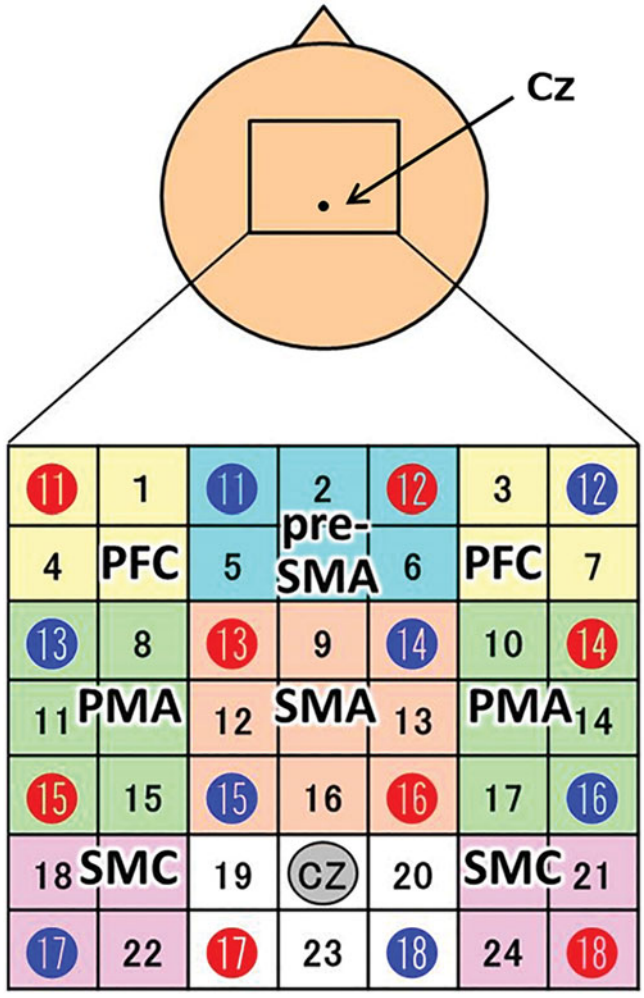

Figure 3. NIRS channel probe sets. NIRS channels were positioned according to the international 10–20 electroencephalography placement system, and the Cz electrode was positioned as a replicable marker of the probes. The SMC, PMA, PFC, PreSMA, and SMA were assessed as the regions of interest. NIRS: near-infrared spectroscopy; PFC: prefrontal cortex; PMA: pre-motor area; PreSMA: pre-supplementary motor area; SMA: supplementary motor area; SMC: supplementary motor cortex.

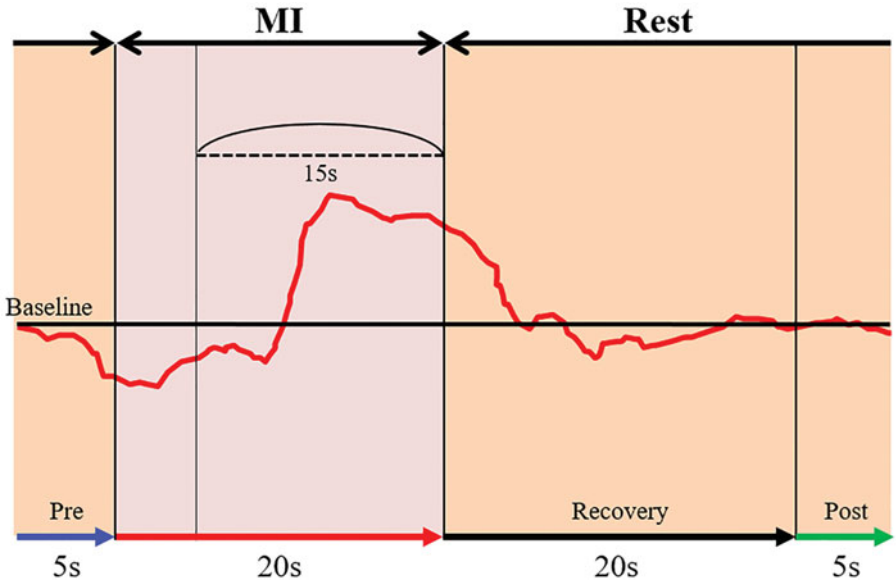

Figure 4. Method for calculating oxy-Hb changes. Linear fitting was applied to the data between pre-task (blue arrow) and post-task (green arrow) periods. The thick black arrow above the red curve indicates the MI period, and the thin arrow indicates the rest period. The vertical axis represents oxy-Hb concentration (mMmm), and the horizontal axis represents the time course of one cycle. The first 5 s of the MI tasks were excluded from the analyses. The final 5–20 s (total 15 s) of the task period were used for the analyses. MI: motor imagery; oxy-Hb: oxygenated haemoglobin.

Electromyography measurements

Surface electromyography (Neuropack Sigma MEB-5504, Nihon Kohden, Japan) was used to monitor the participants' muscles and to ensure that they did not move. The electromyography electrodes were positioned over three spots as follows: the left masseter muscle and the right and left first dorsal interosseous muscles, which are related to self-feeding activities. The electromyography frequency waves fluctuated between 5 Hz–3 kHz and were converted to digital data with a sampling rate of 2 kHz using an A/D conversion device (PowerLab16/30, AD Instruments, Australia). The electromyography measurements showed that the finger and face posture were unaltered in each participant, with no evidence of obvious muscle activation. Thus, all the participants' data were included in the analyses.

Statistical analysis

VAS values, mean oxy-Hb values, and peak oxy-Hb time during the MI tasks were calculated for both conditions (dominant MI and non-dominant MI). The Wilcoxon's signed-rank test was used to examine differences in VAS values between the dominant MI and non-dominant MI conditions. Two-way repeated measures analysis of variance (ANOVA) was performed with the "regions of interest" (PreSMA, SMA, L-PFC, R-PFC, L-PMA, R-PMA, L-SMC, R-SMC) and "condition" (dominant MI, non-dominant MI) as within-subject factors, to examine oxy-Hb differences, both regarding the mean oxy-Hb values and peak oxy Hb times. The peak times in all participants were compared using Bonferroni test, while effect sizes were calculated for the mean values and peak times. In addition, in order to reveal the haemodynamic correlations between regions of interest, raw oxy-Hb data were converted to oxy-Hb *z*-score data, and the relationships among regions of interest were determined. The *z*-score represents the value with a mean value of 0 and a standard deviation of 1 (Tsunashima and Yanagisawa 2009). The *z*-score was automatically calculated for each participant using the ETG-4000 system. Next, Spearman's rank correlation was used to examine the relationship between cerebral haemodynamics and regions of interest during MI. The statistical analysis software Statistical Package for the Social Sciences (Version 22.0, IBM, Japan) was used for data analysis. Differences with a p-value <0.05 were considered as statistically significant, while differences with a p-value <0.10 were considered to indicate a trend towards significance.

Results

Comparison of subjective MI vividness between MI conditions

There was no significant difference in subjective MI vividness between the dominant and non-dominant MI conditions. However, the mean VAS value of the dominant MI condition was higher than that of the non-dominant MI condition, showing a trend towards significance ($p = 0.073$, $Z = -1.793$, Figure 5; S2 Dataset).

Comparison of haemodynamics between MI conditions

The time course of oxy-Hb changes during MI (all participants' grand average waves) is shown in Figure 6 (S3 Dataset). Two-way ANOVA for the mean oxy-Hb values revealed a significant "regions of interest × condition" interaction [$F_{(7,13)} = 2.115$, $p < 0.05$, $\eta^2 = 0.111$], whereas there was no main effect of "region of interest" [$F_{(7,13)} = 0.753$, $p > 0.05$, $\eta^2 = 0.041$] or "condition" [$F_{(1,19)} = 0.250$, $p > 0.05$, $\eta^2 = 0.014$]. The peak oxy-Hb time in each region of interest for the non-dominant versus dominant MI were as follows: PreSMA: 10.8 s versus 11.4 s; SMA: 11.8 s versus 12.0 s; L-PFC: 10.9 s

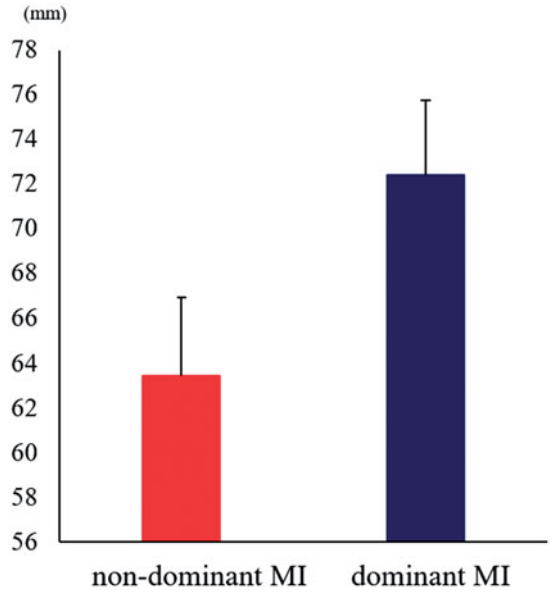

Figure 5. Comparison of VAS scores between motor imagery conditions. The VAS data were analysed using Wilcoxon's signed-rank test. The red bar indicates the mean oxy-Hb value during the non-dominant MI task, whereas the blue bar indicates the mean oxy-Hb value during the dominant MI task. The mean dominant MI value was higher than the mean non-dominant MI value, and the results showed a trend towards a statistically significant difference. MI: motor imagery; oxy-Hb: oxygenated haemoglobin; VAS: visual analogue scale.

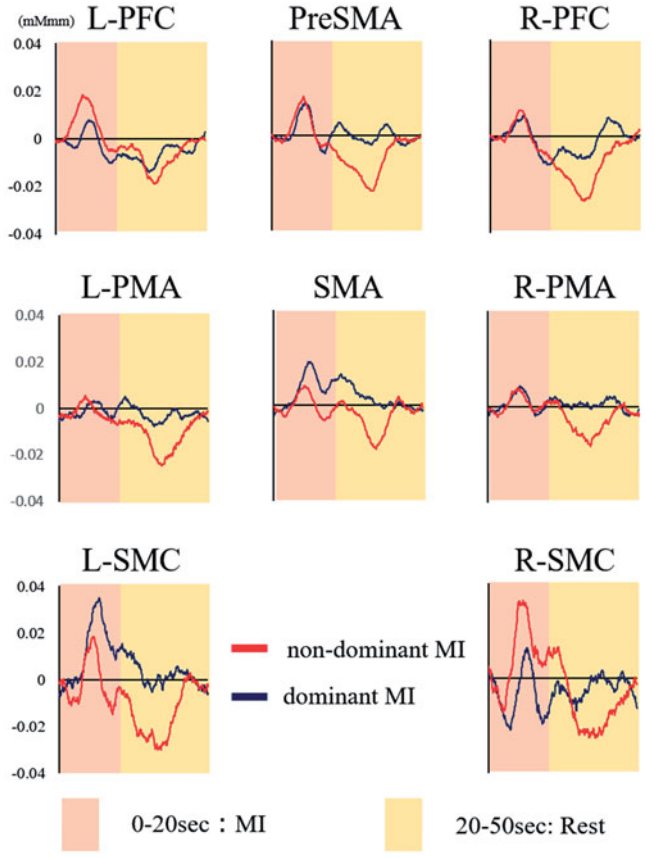

Figure 6. Time course of oxy-Hb changes. The time course of oxy-Hb changes during MI (all participants' grand average waves) is shown. The waveform was calculated by averaging the data measured over three cycles in a block design. The red line indicates oxy-Hb changes during the non-dominant MI task, and the blue line indicates oxy-Hb changes during the dominant MI task. The pink background indicates the MI task time (0–20 s), while the skin-coloured background indicates the rest time (20–50 s). MI: motor imagery; oxy-Hb: oxygenated haemoglobin.

versus 10.6 s; R-PFC: 8.6 s versus 9.9 s; L-PMA: 12.9 s versus 12.1 s; R-PMA: 11.7 s versus 10.9 s; L-SMC: 12.0 s versus 11.1 s; and R-SMC: 9.7 s versus 11.6 s. Two-way ANOVA for the peak oxy-Hb times revealed a significant main effect of "regions of interest" [$F_{(7,13)} = 2.626$, $p < 0.05$, $\eta^2 = 0.169$], whereas there was no main effect of "condition" [$F_{(1,19)} = 0.030$, $p > 0.05$, $\eta^2 = 0.001$] or "regions of interest × condition" interaction [$F_{(7,13)} = 1.194$, $p > 0.05$, $\eta^2 = 0.049$]. Bonferroni test revealed significant differences in the peak oxy-Hb times were observed between the SMA and R-PFC ($p = 0.050$) and between the R-PFC and L-PMA ($p = 0.046$).

Relationship between haemodynamics and regions of interest for the MI conditions

Based on the significant "region of interest × condition" interaction, we examined the relationship between cerebral haemodynamics and regions of interest during MI. The correlation results are shown in Tables 1, 2, and Figure 7. The data were converted from raw oxy-Hb levels to oxy-Hb *z*-scores. A total of 25 statistically significant correlations were found for the regions of interest in dominant MI data, and these were spread across both hemispheres. In contrast, only 17 statistically significant correlations were found for the regions of interest in non-dominant MI data, and these were only found within the left hemisphere.

Discussion

In this study, we used NIRS to investigate cerebral haemodynamics during MI of self-feeding with chopsticks. Our aim was to verify if there were cerebral activation differences between dominant and non-dominant MI conditions. We found that vividness during dominant MI tended to be significantly higher than that during non-dominant MI. There was no main effect of "region of interest" or "condition," but we found a significant "region of interest × condition" interaction for the mean oxy-Hb values. Moreover, we observed significant differences in the peak oxy-Hb times between the SMA and R-PFC, as well as between the R-PFC and L-PMA. In addition, more correlations among regions of interest were found during dominant than non-dominant MI.

In the present study, we found that vividness during the dominant MI task, which involved skilful manipulation of chopsticks, had a mean value that tended to be higher than that during the non-dominant MI task, which involved non-skilful manipulation of chopsticks. A previous study using functional magnetic resonance imaging combined with transcranial magnetic stimulation reported a significant activation only in the right precentral gyrus during a complex MI task performed with the left hand, as compared to performed with the right hand, although there were many overlapping activation areas between the two tasks (Kuhtz-Buschbeck et al. 2003). Another functional magnetic resonance imaging study suggested that the neural correlates for the imager's

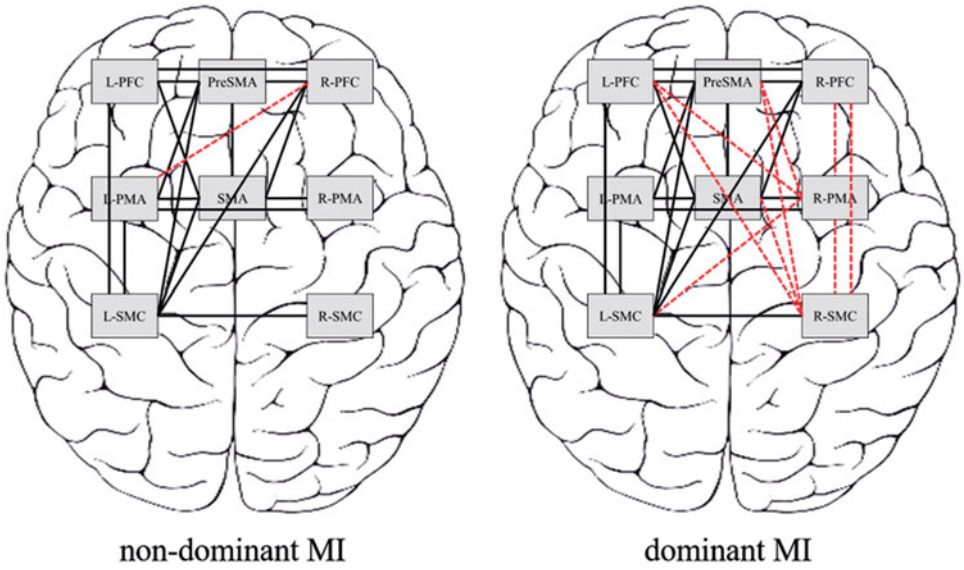

Figure 7. Haemodynamic correlations during motor imagery. The oxy-Hb *z*-scores were analysed using Spearman's rank correlation. The regions of interest connected by black lines represent significant correlations in both conditions. The regions of interest connected by red dotted lines represent significant correlations in one condition. Regions-of-interest correlations were found in both hemispheres for the dominant MI condition but only in the left hemisphere for the non-dominant MI condition. MI: motor imagery; oxy-Hb: oxygenated haemoglobin.

Table 1. Haemodynamic correlations for motor imagery of the dominant hand.

(ρ)	PreSMA	SMA	L-PFC	R-PFC	L-PMA	R-PMA	L-SMC	R-SMC
PreSMA	1.000							
SMA	0.75*	1.000						
L-PFC	0.883*	0.574*	1.000					
R-PFC	0.792*	0.451*	0.74*	1.000				
L-PMA	0.617*	0.792*	0.402	0.326	1.000			
R-PMA	0.794*	0.771*	0.735*	0.492*	0.659*	1.000		
L-SMC	0.74*	0.534*	0.656*	0.642*	0.533*	0.561*	1.000	
R-SMC	0.719*	0.515*	0.626*	0.604*	0.451	0.56*	0.862*	1.000

PFC: prefrontal cortex; PMA: pre-motor area; PreSMA: pre-supplementary motor area; SMA: supplementary motor area; SMC: sensorimotor cortex.
*$p < 0.05$ by Spearman's rank correlation.
The oxygen-haemoglobin (oxy-Hb) *z*-scores were analysed using Spearman's rank correlation. The shaded cells with asterisks indicate significant correlations. Twenty-five significant correlations were found.

Table 2. Haemodynamic correlations for motor imagery of the non-dominant hand.

(ρ)	PreSMA	SMA	L-PFC	R-PFC	L-PMA	R-PMA	L-SMC	R-SMC
PreSMA	1.000							
SMA	0.746*	1.000						
L-PFC	0.725*	0.561*	1.000					
R-PFC	0.707*	0.66*	0.537*	1.000				
L-PMA	0.721*	0.883*	0.421	0.568*	1.000			
R-PMA	0.444	0.532*	0.296	0.245	0.597*	1.000		
L-SMC	0.771*	0.621*	0.782*	0.776*	0.65*	0.297	1.000	
R-SMC	0.272	0.104	0.463	0.412	0.088	0.201	0.661*	1.000

PFC: prefrontal cortex; PMA: pre-motor area; PreSMA: pre-supplementary motor area; SMA: supplementary motor area; SMC: sensorimotor cortex
*$p < 0.05$ by Spearman's rank correlation.
The oxygen-haemoglobin (oxy-Hb) *z*-scores were analysed using Spearman's rank correlation. The shaded cells with asterisks indicate significant correlations. Seventeen significant correlations were found.

perceived MI vividness are very specific (Lorey et al. 2011). Based on the above, MI vividness might have affected haemodynamics and may be dependent on the given MI task.

In this study, there were no significant differences in oxy-Hb mean values, indicating that oxy-Hb levels equally increase during dominant and non-dominant MI of self-feeding using chopsticks. However, peak oxy-Hb times were significantly different between the SMA and R-PFC and between the R-PFC and L-PMA, indicating that peak oxy-Hb during self-feeding MI tasks occurs significantly earlier in the R-PFC than in the SMA or L-PMA. In addition, we converted the raw haemodynamic data to z-score data, in order to examine the dynamic oxy-Hb relationships among regions of interest. Haemodynamic response correlations were found both for the right and left hemispheres during dominant MI; however, such correlations were found only in the left hemisphere during non-dominant MI.

A previous study using NIRS, which investigated cerebral haemodynamics during swallowing ME and MI by comparing patients with cerebral lesions and healthy participants, showed that the peak oxy-Hb time during MI is longer in patients with cerebral lesions than in healthy adults (Kober et al. 2015). This result implies that if participants find it difficult to execute the MI, the peak oxy-Hb time is prolonged. Thus, we hypothesised that the peak oxy-Hb time during the non-dominant MI task, which is more difficult to execute, would be longer than that during the dominant MI task, which is easier to execute. However, our results indicated no statistical differences in the peak oxy-Hb time between the two conditions. In addition, the peak oxy-Hb times were significantly different between the R-PFC and SMA and between the R-PFC and L-PMA during self-feeding MI. Nevertheless, these results are not yet sufficient to discuss the underlying mechanisms. Thus, we could not clearly conclude whether difficulty in performing MI is associated with the peak oxy-Hb time. Hence, further research is required on this topic.

Previous MI studies have reported that MI is executed dominantly by the left hemisphere (Stinear et al. 2006), and

that it is more difficult to activate the right than the left hemisphere using MI tasks (Wang et al. 2014). Moreover, in a study that compared brain connectivity, stronger connectivity was observed in the left hemisphere, including the SMC, PMA, and SMA during a dominant MI task in healthy adults, while stronger connectivity was observed in the right hemisphere during the same task in patients with right hemiplegia (Wang et al. 2016). Therefore, cortical activation occurs primarily in the left hemisphere during MI tasks; however, the left and right hemispheres are connected to each other, and it is possible that the connectivity strength is reflected by MI vividness. Hence, it is possible that haemodynamic correlations are affected by MI vividness, as more correlations among regions of interest were found during dominant MI. This means that, in the case of the self-feeding activity with chopsticks, it was more difficult for participants to perform MI vividly during the non-dominant MI condition (i.e., manipulate the chopsticks with the left hand), which is representative of movement non-proficiency, than during the dominant MI condition (i.e., manipulate the chopsticks with the right hand), which is representative of movement proficiency. That may explain why the haemodynamic response correlations among regions of interest were limited in the non-dominant MI condition.

Research limitations

In this study, the participants were all right-handed healthy adults who were skilful at chopsticks manipulation; thus, it is unclear whether our results are generalisable to left-handed individuals and those with disease, disability, or who are not skilful with chopsticks. Second, no participants reported a very low rate of MI vividness; therefore, it remains unclear whether haemodynamic differences would be observed between participants with high and low MI vividness. Third, it is unclear whether the MI of self-feeding results in similar haemodynamics responses as the ME of the same self-feeding activity or other ADLs. Finally, the sample size of our study was small. Based on these limitations, future studies should include patients with various conditions who might benefit from mental practice of various tasks, including left-handed subjects, and should compare MI with ME of self-feeding activity. In addition, cerebral activation during MI of other ADLs should be assessed.

Conclusion

The haemodynamic response correlations were spread across both hemispheres during MI with the dominant hand but were restricted to the left hemisphere during MI with the non-dominant hand. These differences suggest that MI vividness differences are caused by movement proficiency differences, which may affect haemodynamic responses. The present study provides further insight regarding MI, as well as new ideas about the use of MI for rehabilitation of ADLs. Thus, our results may contribute to the development of a standardised methodology for mental practice using MI in rehabilitation.

Disclosure statement

No potential conflict of interest was reported by the authors.

Data availability statement

Data sets are available with clicking the links of cited supplemental online materials in the text.

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