Relationship between motor area activity during observation and subsequent imitation performance of sequential actions

Kazuma Oki (P), and Sotaro Shimada
School of Science and Technology, Meiji University, Japan
E-mail: ce11020@meiji.ac.jp

Abstract—In the present study, we investigated whether motor area was activated during observation of sequential actions in relation to the subsequent imitation performance. We found a significant correlation between the imitation score and the motor area activity, indicating that the motor area is involved in imitation learning.

Keywords—mirror neuron system, imitation learning, action observation, near-infrared spectroscopy

1. Introduction
Mirror neuron system (MNS) is considered to play an important role in understanding and imitation learning of other’s action. A previous study showed that activity in inferior frontal and parietal cortices during action observation is increased when participants intended to subsequently reproduce the observed action [1]. Another study reported that the primary sensorimotor area is also involved in imitation learning [2].

In our previous study [3], we investigated how unnaturalness (jerkingness) of an action affects MNS by inserting short pauses in the middle of the observed action. The result showed that the sensorimotor area was activated when the subjects observed an action being inserted a few pauses in the middle action. However, when the subjects observed an action with more pauses, the sensorimotor area showed to be ‘deactivated’. This suggests that a slightly, not largely, jerky action would enhance MNS activity.

The present study investigated whether the sensorimotor area activity show a correlation with performance in imitation learning of sequential actions. The brain activity throughout the experiment was measured by near-infrared spectroscopy (NIRS) as in our previous study [4]. In so doing, slightly jerky actions were utilized in order to modulate MNS activity. We predict that jerky actions would enhance the MNS activity and lead to a higher imitation performance.

2. Method
2.1 Subjects
Twelve healthy subjects participated in the experiment (twelve males, age 19-24). Written informed consent was obtained from all participants. The experiments were approved by the local ethics committee.

2.2 Procedure
The subjects observed videos in which a human model put a puzzle together in a transparent box. The puzzle consisted of ten pieces (Fig.1). The action sequences lasted for 70s. The same action sequence was repeated three times, intermitted with a rest period of 25s. We prepare two different action sequences of the model to solve the puzzle (pattern-1 and pattern-2). In addition to the original stimuli (no-pause), we prepare another video stimulus by inserting two short pauses (0.07s for each) in the middle of each action. By inserting a pause into an action, the action seems jerky (unnatural). First pause was put between when pinching a piece and when setting the piece off the box. Second pause was put between when setting a piece off the box and when setting back model’s hand at first position. Thus, there were four experimental conditions (2 patterns × 2 pause conditions). The subject was instructed to watch the video and later solve the puzzle with the same sequence as the video demonstration. The order of experimental conditions was counterbalanced across subjects.

2.3 NIRS measurement
The brain activity in C3 of the 10/2 system was measured with NIRS through the experiment. The arrangement of NIRS probe is shown in Fig.2.

Fig.1 Tridimensional puzzle

Fig.2 Arrangement plan of the NIRS’s probe
2.4 Data analysis

We calculated the effect size of the acquired NIRS data. We defined the behavioral score of the puzzle as follows. If the subject picked up the piece in the same order as the demonstration, the subject gets one point. If the subject set the piece at the same position in the box as the demonstration, the subject gets one point. The perfect score was thus twenty points. We calculated the correlation between the NIRS data and the behavioral score to see whether there was a relationship between motor area activity during observation and imitation performance.

After the imitation experiment, an additional motor task was conducted. The subjects were instructed to pinch a piece and to set in the box, and put out from the box. The subjects conducted the action to set a piece in the box, and then put a piece out from the box seven times. Duration of the action and the rest was 5s and 10s respectively. The brain activity was measured with NIRS, during action execution.

3. Result

There was a significant difference in behavioral score between pattern-1 and pattern-2. The score for pattern-2 (18.3 ± 3.87 points) was significantly greater than pattern-1 (14.3 ± 5.26 points, t(11)=2.29, p<0.05). The effect size of the NIRS data for pattern-2 was also significantly greater than that for pattern-1 in a channel located near C3 (t(11)=3.43, p<0.05, ch-6; Fig.3) The same channel was also activated when the subject performed the action themselves (t(11)=2.20, p<0.05). However, there was no significant difference between the jerky and the normal action condition.

There was a significant correlation between NIRS data and the behavioral score (r= 0.39, P<0.05, ch-6; Fig.4). Since NIRS data for the trial where the subject performed perfectly may not properly reflect the imitation learning process (‘too easy’), we examined the correlation without those trials (10 trials) As a result, there was a much higher correlation between the behavioral score and the NIRS data (r= 0.72, P<0.05).

4. Discussion

We investigated the relationship between motor area activity during observation and imitation learning of sequential actions. We anticipated that the motor area activity was greater when the subjects observed a jerky action than a normal action. However, there was no difference in NIRS data between the jerky action and the normal action conditions. In our previous study [2], we found that several motor areas were significantly activated in the condition where one pause was inserted in the action (P<0.05, t-test), while those areas showed a tendency to deactivate in the condition where more (three) pauses were inserted (P<0.1). Taking these results into account, we consider that the brain activity for the jerky action might be varied across the subjects. That is, some subjects showed greater activity when they observed the jerky action than the normal action, while the others showed the opposite pattern. The NIRS data thus showed no difference between the jerky and the normal action conditions.

On the other hand, we found a significant difference between the pattern-1 and the pattern-2 (action sequences) stimuli both in NIRS and behavioral data. The pattern-1 appeared to be more difficult than the pattern-2 (p<0.05). The brain activity was greater for the pattern-2 than for the pattern-1 (P<0.05), and showed a significant correlation with the behavioral data. In a previous study [1], the subject observed the video in which a model assembled a toy, which was consisted of six parts. The inferior frontal and parietal cortices were activated during observation, and its degree was correlated with the imitation performance. Our result is in line with this previous study, and expands the finding to that the motor area near C3 (presumably the primary motor area) is also involved in imitation learning.

References