

Influence of Motor Imagery Incorporating Material Perception on Spinal Anterior Horn Cells

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Abstract

Introduction: We consider that an image of material perception activates a real and vivid motor image in motor imagery (MI) tasks, such as visualizing grasping movements during rehabilitation. However, no studies have examined whether the excitability of spinal neural function is affected by visualizing the tactile perception of the object to grasp. In this study, we measured the excitability of spinal neural function during MI tasks by using F-waves, and examined the influence of visualizing material/tactile perception on the excitability of spinal anterior horn cells.

Methods: Task 1, F-waves were recorded while the subject placed his hand lightly on a ball and visualized maximum isometric contraction grasping force in a functional position with isometric opponens pollicis activity. Task 2, F-waves were recorded while the subject placed his hand lightly on a baseball and visualized maximum isometric contraction grasping force in a functional position with isometric opponens pollicis activity, while perceiving the material, including the stitches, of the baseball during the MI. The results of Tasks 1 and 2 were analyzed with a paired t-test.

Results: The results also showed that the facilitation was greater in the second task when the subject visualized both the grasping movement as well as perceiving the material, compared to the first task when only the grasping movement was visualized.

Conclusion: MI involving material perception influenced the excitability of spinal anterior horn cells. In the future, we plan to examine the usefulness of MI intervention incorporating material perception in many patients with extrapyramidal diseases.

Keywords: Motor imagery; Touch perception; F-wave

Introduction

Motor imagery (MI) can activate the same neural structures as those activated during motor execution (ME). Jeannerod proposed a concept of functional equivalence between MI and ME [1]. It is expected that MI can improve motor function even when physical activity is limited by medical conditions or when exercise is difficult. In recent years, MI has been applied in the field of rehabilitation. Until now, various studies have demonstrated that MI activates neural networks in the cortical and subcortical areas that are involved in motor execution.

Holmes et al. [2] proposed the PETTLEP model consisting of seven elements (Physical, environment, task, timing, learning, emotion and perspective) for improving the efficacy of MI. According to this model, simple motor imagery instruction is not enough. Regarding the environmental factors in the PETTLEP model, the vividness of MI is influenced by external factors such as somatic, visual and auditory cues.

The influence of stimuli via various sensory modalities needs to be considered for creating vivid MI. In daily life, we can have a tactile image of a material by just seeing it without touching it. Materials have different properties that make them useful for different purposes, and they are associated with meaningful functions in daily life. For example, cups are usually made of glass, ceramics or metal and they are hardly made of cloth or leather. Material perception is a process that provides biologically important information, ranging from sensory impression to functional meaning. It is assumed that learning in the postnatal developmental process plays an important role in acquiring information related to material perception [3]. We consider that an image of material perception activates a real and vivid motor image in motor imagery tasks, such as visualizing grasping movements during rehabilitation.

Numerous studies have demonstrated that MI activates the central nervous system and increases the excitability of spinal neural function [4].

Regarding material perception, Cant et al. conducted a study using functional magnetic resonance imaging (fMRI) and showed that the ventral visual pathway was involved in the process [5,6]. However, no studies have examined whether the excitability of spinal neural function is affected by visualizing the tactile perception of the object to grasp. In this study, we measured the excitability of spinal neural function during MI tasks by using F-waves, and examined the influence of visualizing material/tactile perception on the excitability of spinal anterior horn cells.

Subjects and Methods

Subjects

The sample consisted of 10 healthy right-handed adult men (age, 21.3 ± 4.8 years). The subjects were active baseball pitchers who volunteered to participate in this study after the purpose and methods of the study were explained to them verbally and in writing.

This study was conducted after approval by the ethics committee of Heisei Medical College (approval number, H27-25). The experiments were conducted in accordance with the Declaration of Helsinki.

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Methods

The ability of the subjects to rotate mental images was assessed with a mental rotation task of the hands. The measurement was performed using a web application called Recognize Online, developed by the Neuro Orthopedic Institute (Australasia). In this task, 20 pictures of hands (right or left) were randomly presented, and the subjects were asked to discriminate between right and left hands. The mean correct response rate and mean response time for right and left hands were calculated.

Measurement of spinal anterior horn cells excitability: Subsequently, F-waves were used to measure the excitability of spinal anterior horn cells by using evoked electromyography MEB-9402 (Nihonkoden, Tokyo, Japan). During the experiment, the subjects were seated in a chair with their forearms and hands placed on a table, while the shoulders were in a neutral, mildly flexed position in the internal and external rotation and the elbow was flexed at 60°. The measurement was performed according to Kimura's procedure [7]. F-waves were recorded from the abductor pollicis brevis muscle following stimulation of the median nerve at the wrist with a supramaximal stimulus, according to the "belly tendon" method. A total of 16 consecutive 1 Hz stimulations were applied. The band pass filter was set at 1 Hz to 3 KHz. The mean F-wave amplitude obtained from 16 stimulations was calculated, and the F/M amplitude ratio, defined as the mean amplitude of all responses divided by the maximum amplitude of the M-wave, was used for the analysis.

The subject was asked to place the hand lightly on a ball in a functional position with isometric opponens pollicis activity in order to obtain F-waves at rest. Next, MI tasks were randomly performed. In Task 1, F-waves were recorded while the subject placed his hand lightly on a ball and visualized maximum isometric contraction grasping force in a functional position with isometric opponens pollicis activity. In Task 2, F-waves were recorded while the subject placed his hand lightly on a baseball and visualized maximum isometric contraction grasping force in a functional position with isometric opponens pollicis activity, while perceiving the material, including the stitches, of the baseball during the MI. The diameter of the ball in Task 1 was the same as that of the ball in Task 2, although the ball in Task 1 had no stitches.

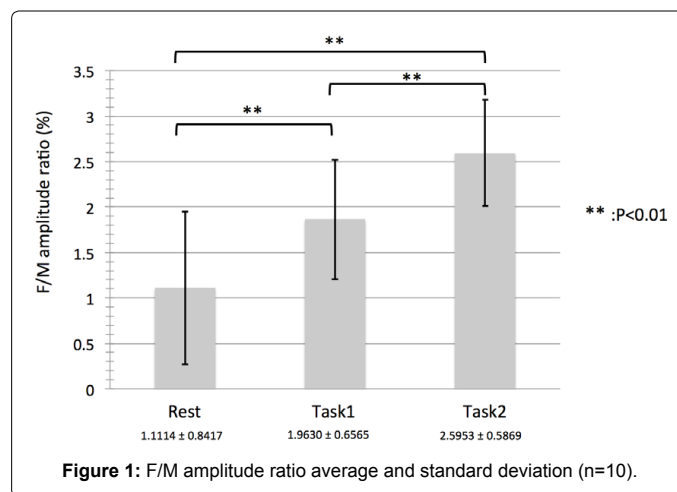
Vividness evaluation after the imagery tasks: Immediately after each task, the vividness of the image was evaluated with the movement imagery questionnaire-revised (MIQ-R) developed by Hall et al. [8] scored using a 7-point kinesthetic imagery scale (1, very hard to feel; 2, hard to feel; 3, somewhat hard to feel, 4, neutral; 5, somewhat easy to feel; 6, easy to feel; 7, very easy to feel).

In addition, the subjects were verbally instructed not to move their fingers or apply force during the MI tasks. Each measurement was performed after confirming (using electromyography) that the subject was not applying any force before starting the measurement.

Data analysis: The results of Tasks 1 and 2 were analyzed with a paired t-test and the results of the evaluation of visualization ability were analyzed using the Wilcoxon's signed-rank test using SPSS Statistics 21.0. Results with $p < 0.05$ were considered statistically significant.

Results

The results of the evaluation of visualization ability (ability to rotate mental images) showed that the mean correct response rate was 90.00 (± 11.95)% for pictures of the right hand and 85.00 (± 7.56)% for pictures of the left hand. Although all the subjects were right-handed, there was no significant difference between the correct response rates for pictures of the right and left hands. In addition, the mean response



time for each picture was 1.28 (± 0.27) s for pictures of the right hand, and 1.28 (± 0.29) s for pictures of the left hand, showing no significant difference between the two types of pictures. There were no subjects showing a markedly low correct response rate or a marked delay in the response time.

F/M amplitude ratio

The F/M amplitude ratio and standard deviation in each task are described in Figure 1. The F/M amplitude ratio significantly increased while visualizing isometric contraction during Tasks 1 and 2 (Rest < Task 1, $p = 0.01$; Rest < Task 2, $p = 0.00$). In addition, the F/M amplitude was significantly higher in Task 2 (Task 1 < Task 2, $p = 0.00$), wherein a grasping movement was visualized while perceiving the material, including the stitches, of the baseball.

Vividness evaluation after the imagery tasks

The median value of vividness evaluated after the imagery tasks was 4.5 (Interquartile Range: 2) in Task 1 and 3 (Interquartile Range: 2.25) in Task 2 and the difference between them was not statistically significant.

Discussion

In daily life, tactile perception of materials is always preceded by visual input and thus, the individual has information about the object in advance. The subjects of this study were considered to have sufficient prior information about the baseball because they were baseball pitchers who touched baseballs every day. In addition, considering that the pitchers are particularly careful about the material, including the stitches of the ball, when they are throwing them, they are considered to pay more attention to the stitches, which may enhance their material perception ability. Klatzky et al. [9] reported that certain information regarding the bumps and dents and smoothness of the surface elicited an urge to touch. Considering this, we used baseball pitchers as the subjects in this study because they were considered to be able to evoke MI of grasping movements while perceiving the material of the ball.

The H-reflex and F-waves recorded from the muscles after percutaneous electrical stimulation of the innervated nerve are used for evaluating the excitability of spinal anterior horn cells. In general, F-waves are used for the evaluation of upper extremities because fewer muscles in the upper extremities are suitable for recording the H-reflex [10]. In addition, the F-wave is a compound action potential evoked by the electrical stimulation of a peripheral nerve, in which the impulse

travels retrogradely to the spinal anterior horn cells and then travels anterogradely. The shape of F-waves is different from one another, and the amplitude is thought to reflect the excitability of spinal anterior horn cells [11]. As the amplitude of F-waves varies greatly, the F/M amplitude ratio, defined as the mean amplitude of F-waves divided by the maximum amplitude of the M-wave, was used for the analysis.

A study found that a longer response rate in the mental rotation task administered before F-wave recording, was associated with lower MI ability [12]. In the present study, none of the subjects showed a marked delay in the response time, and all of them were included in the statistical analysis.

The results of the present study showed that the excitability of spinal anterior horn cells increased by just visualizing grasping the ball as well as by visualizing grasping the ball while perceiving its material. The results also showed that the facilitation was greater in the second task when the subject visualized both the grasping movement as well as perceiving the material, compared to the first task when only the grasping movement was visualized. The physiological mechanism underlying this facilitation may be explained by the fact that prior visual information can facilitate material perception and that sensory information obtained from touching makes the imagery more real. In addition, it can possibly elicit a motor memory stored in the cerebellum, which alters the feed forward circuits to the frontal lobe and basal ganglia [13] and descending inputs from both pyramidal and extrapyramidal systems may influence the spinal anterior horn cells and interneurons around the area, or somatic sensation processed in the parietal lobe may influence the motor area and basal ganglia. However, there was no significant difference in the results of the evaluation of imagery vividness between the two conditions. The results indicate that it is difficult to obtain a vivid image with MI of grasping movements, while perceiving the material of the baseball including its stitches.

Conclusion

Stroke survivors with hemiplegia face difficulties in perceiving sensory information due to motor and sensory impairments and experience impaired interactions between the body and the environment. Therefore, exercise therapy for such patients should be individualized based on the patient's clinical status. Brain imaging techniques are often unavailable in clinical practice. In addition, the effects of MI on the excitability of the cortex alone are not valid enough

for this technique to be applied in clinical practice, that is, its effects on spinal neural function also need to be demonstrated. The results of the present study showed that MI involving material perception influenced the excitability of spinal anterior horn cells. MI can be applied in the rehabilitation of patients with severe hemiplegia who cannot move the hand or those who have been prescribed bed-rest.

In the future, we plan to examine the usefulness of MI intervention incorporating material perception in many patients with extrapyramidal diseases.

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