Chapter 4

Clinical Application of Motor Imagery Training

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/67518

Abstract

Motor imagery training is applied to a rehabilitation program based on previous studies regarding neuroscience and behavioral science. Motor imagery training is useful because it can be applied to almost all patients in clinical settings. However, because motor imagery training has some shortcoming, clinicians need to consider its shortcoming. The objective of this chapter is to promote understanding about using motor imagery effectively.

Keywords: motor imagery, motor learning, rehabilitation

1. Introduction

Motor imagery is defined as the process of mentally rehearsing a motor act without overt body movement [1]. Motor imagery basically involves an experience as of movement of body part and action, meaning that the motor imagery is influenced with based on motor representations internally by working memory [2].

Motor imagery is called first-perspective imagery (1PP imagery), that is, image originates from the same viewpoint experienced at encoding [3], different from visual imagery (third-person perspective imagery or 3PP imagery) which is imagining physical movement from an external viewpoint as though observing other people's body movements as an onlooker. In comparison to brain activation during visual imagery, brain activation in the motor-related area (e.g., pre-supplementary area, precuneus, and inferior parietal lobule) was great during 1PP imagery [4].

Many previous studies have shown that neural plasticity and brain activation during motor imagery training are similar to that of actual physical practice of motor learning. Most previous studies demonstrated brain activation in the supplementary motor area, premotor cortex [5–7], and parietal cortex [6]. Additionally, as with changes in the motor neuron, enhancing cortico-spinal excitability during motor imagery led to an increase in the motor-evoked potential (MEP) by using transcranial magnetic stimulation [8, 9]. In behavioral data, there is a similarity between motor imagery and actual performance. Motor imagery is widely recognized as an effective method to enhance motor performance. Currently, motor imagery training is applied in rehabilitation programs in clinical settings. This training, which can be made available to all patients because it does not impose a physical load on patients, was confirmed through clinical evidence from meta-analysis. However, there are some problems with using motor imagery training for elderly people or stroke patients with reduced motor imagery ability and cognitive function. Based on this fact, physical therapists would be recommended to assess patients' motor imagery ability and to apply motor imagery training following the assessment. This chapter (a) addresses the effects of simple motor imagery training for patients such as those who have suffered a stroke and (b) offers three recommendations for resolving the problem of administering the training to patients with reduced cognitive function.

2. Motor imagery training

The biggest advantage of motor imagery training is that, unlike general physical training, there is no limitation on the patient's ability to execute motions because motor imagery is a cognitive activity and does not require physical exertion. Because of this advantage, motor imagery training is currently applied for a wide range of body functions.

For example, Hamel et al. reported the availability of motor imagery training for postural control. This study used imagery intervention for 6 months to enable patients to autonomously maintain a straight standing position, without body sway [10]. In a more recent study, Yasuda et al. reported the beneficial effect of decreased body sway after performing only 20 repetitions of imagining one's own body movement (dorsiflexion-plantarflexion) [11]. For chronic post-stroke patients, Cho et al. demonstrated that postural balances (Fugl-Meyer score (FMS)), functional reach (distance), and gait ability (time required for up-and-go and 10-m walk test) were improved after motor imagery training for normal gait [12].

Previous studies have also shown improved upper extremity function after stroke. Page and his colleagues have demonstrated that motor imagery training has beneficial effects on upper extremity function as measured by the FMS of motor recovery, motor activity log, and action research arm (ARA) test in subacute [13] and chronic patients [14–16]. Particularly, Page's works used randomized control trial to verify the availability of motor imagery training, which contributed to demonstrate high clinical evidence for the enhancement of upper extremity function, measuring ARA test, motor assessment scale, and the FMS in stroke patients [17]. According to Langhorne's report, mental practice (motor imagery training) seems most effective for upper extremity function when conducting meta-analysis. Therefore, this report has shown that motor imagery training had a greater effect than other interventions in established clinical evidence, such as constraint-induced movement therapy [18–21] (where patients are asked to use an affected limb (execute a task) for a long time and for a large number of repetitions under the condition that the intact limb is constrained), robot-assisted therapy [22, 23] (where robotic devices can assist patients' affected limb use in high-intensity, repetitive, specific task by digital control), and electrical interface [24] (where electrostimulation can deliver electric impulses to the muscle through the skin surface and elicit muscle contraction by simulating the neuromuscular system; the intensity, frequency, and patterns of impulse delivery can be selected depending on the patient's condition). The reports investigating the effects of motor imagery training are increasing; however, it must be considered that there are still a very few number of reports verifying the beneficial effects of motor imagery training. This means that additional studies are necessary to establish and accumulate clinical evidence of availability of motor imagery training for improvement of upper extremity by high-evidence level study design. Based on the clinical evidence, motor imagery training is a potential interventional approach for stroke disability [25]. In this report, intervention via motor imagery is an important tool to promote information processing for the improvement of actual motor function.

In almost all previous studies investigating the effects of motor imagery training on motor performance, subjects imagined their body movements while sitting or lying in a relaxed position, with eyes closed. This means that the effects of motor imagery training are influenced by the environmental context and participants' emotional condition. Considering these factors, Holmes and Collins devised the PETTLEP model as a guideline for applying motor imagery training for athletes [26]. PETTLEP is an acronym (Physical, Environment, Task, Timing, Learning, Emotion, and Perspective), with each letter representing an important factor for practitioners to consider when conducting motor imagery training.

The author suggests that the PETTLEP model can be used for some patients in rehabilitation settings considering clinical application. Although PETTLEP model was originally proposed for improving athlete's performance using motor imagery training, athletes in sports settings and patients in clinical settings are in common that both of them improve motor performance via motor-learning process, Therefore, contents in terms of clinical patients will be stated below. *Physical* refers to patients' physical experience when they imagine action (including body position, clothing, and sports equipment specific to the task/situation). In order to produce effective imagery intervention, patients should attempt to physically replicate as much as possible their actual performance. *Environment* refers to the surroundings when the patients imagine their own movement. The surroundings should be replicas of the actual environment of action. *Task* refers to the identicalness of the task imaging to the actual task. This detail would need to be updated regularly as the patient's skill improves. *Timing* refers to the congruence between times for actual action and imagery of the action. Decety et al. reported the temporal coupling and the same neural substrate between actual and simulated movements measured by mental chronometry (refers to inferring the time course of information processing in the nervous system [2, 27]). Therefore, patients have to imagine the action as if they have temporal consistency between the two. *Learning* in the PETTLEP model refers to updating and reflecting the contents of their imagery with improvement of the skill. Some previous studies reported that the structural and functional changes are shown by improving motor skills or practice [28, 29]. Because of that, patients have to refine the contents of their imagery in association with learning processes instead of routine contents of imagery throughout their improvement of the skill. *Emotion* refers to the emotions with which patients perform the actual action. While patients are imagining action, they should attempt to accompany this with the emotions and arousal associated with the typical physical performance. *Perspective* refers to the direction from which the imagery is viewed. 1PP imagery is commonly used for motor imagery training because 1PP imagery involves shared neural mechanisms and functional equivalence, suggesting that 1PP imagery training would be most beneficial. However, some research has demonstrated that 3PP imagery training is more beneficial [30, 31]. Based on these studies, Holms and Collins stated that individuals should combine 3PP imagery with 1PP imagery [26]. These elements of the PLTTEP model would be most important to the improvement of motor function; therefore, clinicians should consider them when applying motor imagery training.

Although it would be certain that the effects of motor imagery training would be influenced by the elements of PETTLEP model, because motor imagery is simple cognitive activity, it would have difficulty for precise and vividness motor imagery in some individuals. Binder pointed out that the clinician cannot comprehend how patients imagine their body movements, and the most concerning limitation of motor imagery is that it is not easy to objectively assess how the subject vividly imagines his or her action. Thus, indirect assessment methods were commonly used as a self-rating scale, for example, MIQ-RS [32, 33], KVIQ [34], mental chronometry, and a mental rotation (MR) task (see below for detail). In particular, some disease conditions involving the central nervous system (CNS) are affected to imagine their body movements. For example, Personnier et al. showed that elderly people decline in motor imagery ability by using mental chronometry of various walking tasks (i.e., subjects actually or mentally walked (walking distance: 5 m) along three paths having different widths (15, 25, and 50 cm)) [35]. In the report, functional changes in the aging brain cause reduced motor imagery ability in elderly people. Patients having upper limb motor dysfunction due to stroke have difficulty imagining their own body movement. Li et al. measured the motor imagery ability of stroke patients by having them imagery performing a sequence of three kinds of movement and then choose from among four options (photograph) of the final posture of the three-sequence movement. The result showed that 1PP imagery was disturbed in stroke patients, but 3PP imagery was not. This suggested that it is difficult for stroke patients to imagine their own actions (1PP imagery) [36]. Also, Decety et al. investigated motor imagery in patients with stroke and spinal cord injuries by measuring mental chronometry. Incongruence between the duration of actual body movement and its motor imagery was shown in stroke patients [37]. Moseley et al. demonstrated that patients with complex regional pain (refractory chronic pain) decrease low motor imagery ability by measuring MR task of hand stimuli. Notably, in the report, the low motor imagery ability is shown at affected body parts but not the unaffected limb. This means that patients who have difficulty imagining their body movement, such as stroke and chronic pain patients, may not benefit from motor imagery training. In fact, motor imagery does not enhance motor recovery in early post-stroke patients [38]. Timmermans et al. reported that video-based motor imagery training was not effective for subacute stroke patients, as measured by the FMS, Frenchay arm test, Wolf motor function test, and accelerometry [39]. Although Page et al. showed the improvement of hand function by motor imagery in acute stroke patients, Ietwaart et al. and Timmermans et al. reported no effect of the training. A possible reason for the inconsistency in results would be different in affected lesion due to brain stroke. The critical lesion site responsible for imagining one's own body movement was the inferior parietal lobule [40]. In this study, subjects were administered transcranial magnetic stimulation (TMS) using theta-burst stimulation to inhibit activity in the left inferior parietal lobule before they performed an implicit sequence-learning task. In comparison with the sham stimulation (control condition), the inhibition of the left IPL impaired the acquisition of motor skills. This study revealed the contribution of the left inferior parietal lobule to motor imagery. Moreover, patients with stroke-disturbed motor imagery were investigated for responsible brain lesions to identify the area responsible for motor imagery. The results showed that stroke patients were damaged in the fronto-parietal network, the left putamen, the left ventral premotor cortex, and long association fibers linking parieto-occipital regions with the dorsolateral premotor and prefrontal areas. In addition to the results of brain activation in the left IPL resulting by Kraeutner's study, these areas indicated a responsible lesion for motor imagery. In any case, these previous studies provide the clinicians with valuable information about the importance of the left brain area during motor imagery. This indicates that the clinicians should consider some possibility of impaired motor imagery ability in patients with left brain damage when the clinicians apply motor imagery training to these patients.

More practical strategies using motor imagery rather than simple motor imagery were verified for some patients having difficulty with motor imagery using a brain machine interface. Mihara et al. measured the changes in hemodynamic responses (associated with neuron behavior reflecting brain activity) using near infrared spectroscopy during motor imagery [41]. In this study, subjects were delivered information on the changes in hemodynamic responses in real time while subjects imagine the finger movements. The hemodynamic changes (i.e., brain activity) in real-time monitoring were greater than in baseline and sham information. This result suggested that the neuro-feedback approach, such as real-time monitoring using near infrared spectroscopy, would enhance brain activity, which was to be expected that subjects can perform mental imagery effectively by using this neuro-feedback approach.

3. Mental rotation task

In order to overcome the shortcomings mentioned above (some patients find it difficult to imagine their body movement precisely and vividly), one idea was to use a mental rotation (MR) task. MR refers to the ability to imagine the rotation of an object in space [42]. In a seminal study by Shepard and Metzler [42], participants were required to judge whether the pairs of three-dimensional objects were the same or different (**Figure 1a**, **b**). The results showed that the time required for the judgment (the MR reaction time) increased as the angle of rotation

3.1. Mental rotation of body parts for motor imagery

An MR task using a visual stimulus of a body part (typically a hand or a foot) requires participants to judge the laterality of a rotated body part (i.e., whether the stimulus is the right or the left hand/foot) (**Figure 2**).

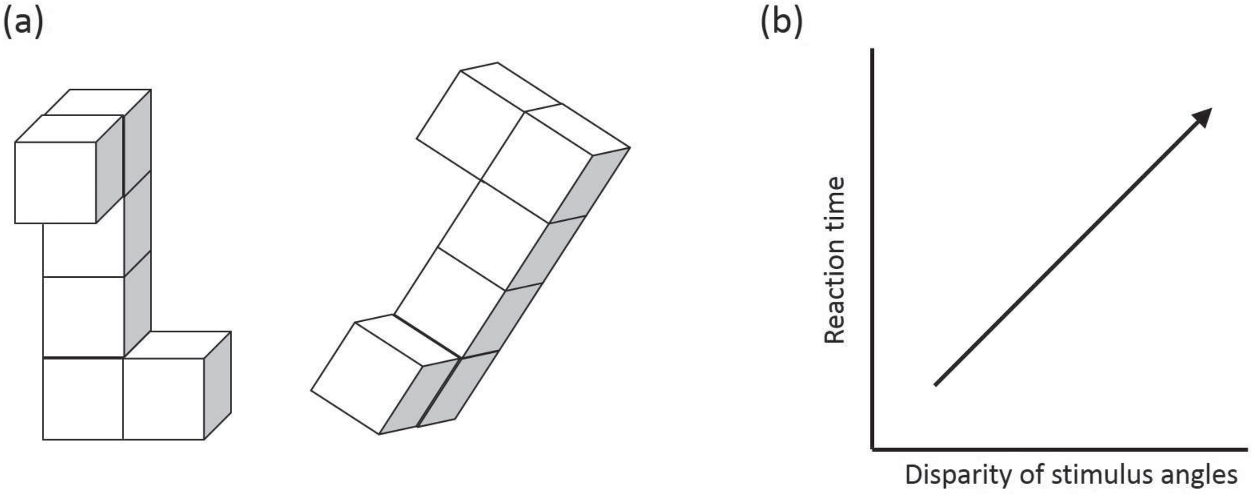

Figure 1. (a) MR task for three-dimensional objects: same-different judgment task. (b) The schematic liner relationship between reaction times (vertical axis) disparity angle of two objects (horizontal axis) [42].

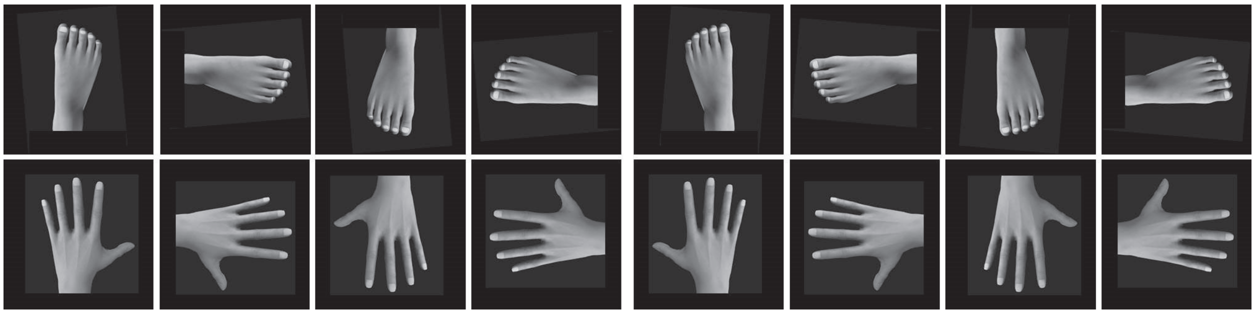

Figure 2. The MR task of body parts stimuli: making judgment of right or left parts.

In an MR task using body part stimuli, the time required for laterality judgment increased with the increasing rotation angle of the stimuli (**Figure 4**, unpublished work) as reaction times for MR task using object stimuli [42]. On the other hand, the time required for the simple reaction in the same MR task using body part stimuli was not significantly different. This suggested that the subject would imagine their own body movement of body parts of MR stimuli during MR task using body part stimuli. More directly, Parsons indicated that the MR of body parts involves cognitive processes used for both motor imagery and motor execution. The author reported that times required for the laterality judgment (i.e., the reaction time) of hand and foot stimuli were related to the times required for actual hand movement [43]. Participants were instructed to (a) judge the laterality as quickly and accurately as possible and (b) execute a hand/foot movement in a stimulus orientation. As a result, the reaction times for the hand/foot and the times required to execute these movements are nearly equivalent (e.g., the reaction time for 180° is similar to the time of actual hand movement of 180°). Parsons concluded that participants mentally rotate their own body image into congruence with the rotating stimuli during the MR task. Therefore, that study indicated that the MR of body parts can determine the ability to operate one's body image (i.e., the ability to operate motor imagery) by measuring the reaction time.

A more recent study by Ionta et al. showed that, during the MR of body parts, individuals simulate to move their own body image so as to match the observed stimulus [44]. They compared the MR reaction times for hand and foot stimuli in two postural conditions: (a) an anatomical posture (i.e., participants positioned their hands on their knees) and (b) an unusual posture (i.e., they positioned their hands behind their back, with fingers intertwined). The results showed that the MR reaction times for hand stimuli, but not for foot stimuli, were delayed in the unusual posture condition. Even if a stimulus was presented with no rotation, the reaction time was delayed when individuals kept their hands behind their back, so that the orientation of the hands was different from that of the stimuli. Ionta et al. concluded that the MR of body parts was a cognitive task in which individuals simulate moving a specific body part image from its actual posture to that of the same observed or imagined body part [45].

Other previous studies investigating brain science strengthen the evidence that the MR of a body part promotes motor imagery involving the MR stimuli. Many previous reports demonstrated that execution-related motor areas were activated during the MR of body parts (typically the hand). More specifically, brain activation in premotor area and parietal cortex was shown during the MR of body parts. Kawamichi et al. examined the time course of brain activation during the MR of body part (hand) stimuli. This article reported that neuronal activity in the visual cortex was observed approximately 100–200 ms from stimulus onset. Brain activation in the inferior parietal lobe followed (after 200 ms). Notably, brain activation in the inferior parietal lobe showed contralateral dominance in the visual stimulus hemifield. Then premotor area activity started the inferior parietal lobe activity [46]. Moreover, to clarify the importance of the motor area's contribution to the MR of body parts, Ganis et al. examined whether MR performance (reaction time) was hindered when single-pulse TMS was delivered to the representation of the hand in the left primary motor cortex during the MR of pictures of hands and feet [47]. The results showed that the response times for the judgment (MR performance) were slower when TMS was delivered, as compared with a peripheral magnetic stimulation (control stimulation). It was striking that the interference was obtained delivered at 650 ms after hand-picture stimulus onset, and the effects were greater for hand stimuli in comparison with the foot-picture stimulus. These findings indicated that the primary motor cortex is involved in the MR of body parts. In particular, the involvement of the primary motor cortex is (a) relatively late in the processing of MR and (b) stimulus specificity like a physical representation of the human body, located within the brain (the cortical homunculus). This physiological study directly revealed that the cortico-spinal tract (central nervous system in the primary motor cortex to the spinal cord) plays an essential role in performing MR.

Brain activity during MR has been investigated in many previous studies. Zacks investigated brain activity in a meta-analysis of neuroimaging study during MR. This reports showed brain activity in the superior parietal cortex, the motor region in the precentral cortex, and the lateral inferior prefrontal cortex when subjects were performing the MR of body parts [48]. These results support the view that MR depends on motor simulation of the body part stimulation in some situations. Enhanced cortico-spinal excitability during the MR of hand stimuli indicates that the excitement of the motor area is involved in performing the MR of body parts [47]. However, since some studies show no brain activity in the primary motor area, its involvement remains unclear, that is, it is necessary to determine the involvement of primary motor area during the MR of body parts.

3.2. Intervention of mental rotation

Including the author's previous works, it is indicated that the intervention of the MR of body part stimuli would promote improvement of physical function. Kawasaki et al. showed that the reaction time for the MR of foot stimuli (see **Figure 3**) was related to the postural displacement of one foot while standing (the length of body sway), but there was no relationship between that and the reaction time for the MR of hand and car stimuli [49]. Jansen showed similar results in elderly people [50]. These results suggested the availability of an MR task using foot stimuli for the improvement of challenging postural stability, such as one-foot standing, through motor imagery of feet of individuals themselves.

Based on previous research investigating neuroscientific mechanisms during the MR of body parts, the availability of MR using foot stimuli has immediate beneficial effects on postural stability during a challenging posture, such as standing on one foot, but not during bipedal standing. Notably, when the subject performed MR using hand stimuli, these beneficial effects were not obtained. After the report, the beneficial effects of the MR of foot stimuli on the postural stability while standing on one foot for a relatively long time (60 min <) were demonstrated. The long-term effects would be helpful for a discussion about the mechanism of the effects of MR intervention. As stated above, Ganis determined the involvement of cortico-spinal excitability performing the MR of body parts [47]. According to previous reports, the duration of the enhanced cortico-spinal excitability is for a maximum of 30 min after finger movement [51, 52]. Therefore, the long-term beneficial effects for a long time were not completely explained. A possible explanation is motor consolidation, as previous studies have shown that motor memory was

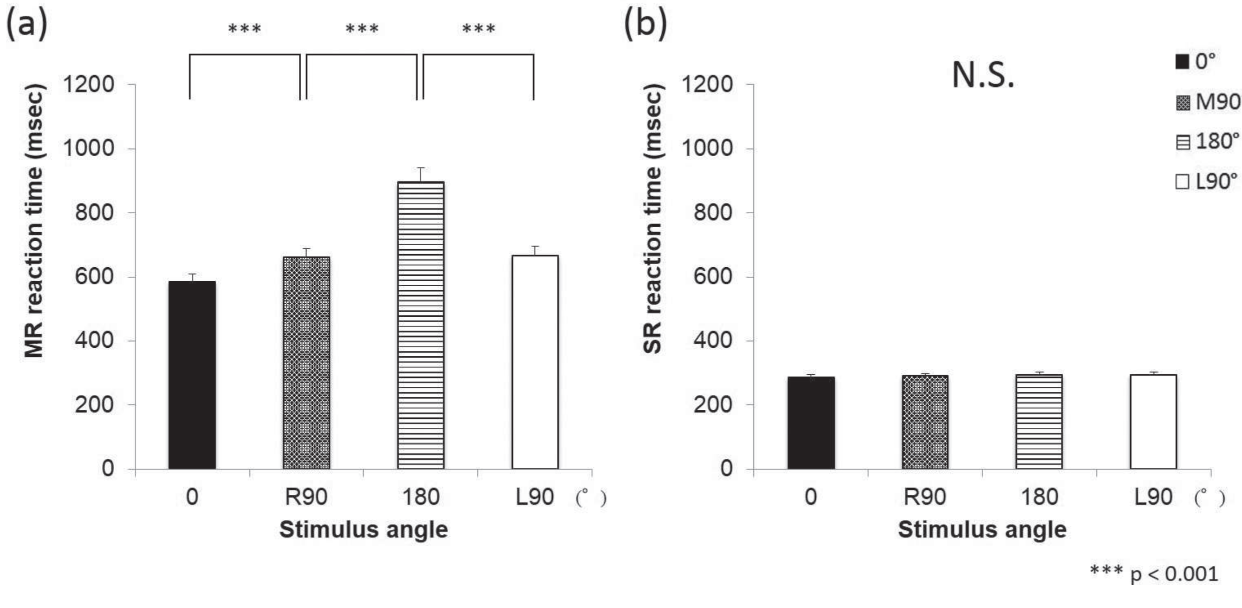

Figure 3. Time required for (a) MR task using foot stimuli and (b) simple reaction for the foot stimuli. The reaction times for MR task using foot stimuli were delayed with rotation angle, but not simple reaction time.

consolidated for more than 24 h after repetitive motor imagery intervention [53]. Considering the findings, the beneficial effects of the MR of foot stimuli on postural stability are ascribed to factors such as the enhancement of cortico-spinal excitability and memory consolidation.

4. Action observation therapy

Action observation therapy refers to learning through observing the behavior of another person as a model; this can be used in clinical settings to encourage motor performance without any physical activity. Action observation therapy involves bottom-up processing based on visual information, which is different from motor imagery training (top-down using a conscious cognitive process) [54]. Several previous studies have reported that observational learning is effective for younger participants [55, 56], and it has also been shown to improve motor performance in patients hospitalized due to stroke with upper or lower extremity hemiplegia [57–59] and in patients with Parkinson's disease [60, 61]. Thus, observational learning has been used for many kinds of patients in clinical settings.

The effect of observing the behavior of another person upon overt motor performance is most commonly attributed to the demonstration of brain activity in the ventral premotor areas, sulcus temporalis superior, and inferior parietal lobe (i.e., mirror neuron system) during action observation [62, 63]. Historically, electrical activity in the rostral part of the inferior area 6 (area F5) of two macaque monkeys was shown both when the monkeys performed a given action and when they observed a similar action performed by the experimenter [64]. Particularly, the F5 area acutely responses to both the observation and execution of actions in terms of the goal (e.g., grasping) and how the goal is achieved (e.g., a precision grip). Human data also revealed that these areas are involved in imitating the actions of others [65–67] and understanding the intention of others' actions [63, 68]. When the beneficial effects of action observation are gained, high activation in the observer's mirror neuron system would be expected to create first-person perspective (1PP) imagery [57, 76], that is, the mental process of the movement without any body movement [69–71]. Ertelt et al. reported that after the action observation therapy, brain activation in the mirror neuron system was increased [57], meaning that such activation is strongly related to the effects of action observation therapy.

Basically, action observation therapy has beneficial effects on motor performance through the activation of the central nervous system (CNS), which is involved in movement by first-person perspective imagery. Actually, there is some condition for more effective activation of the CNS when applying action observation therapy. Based on a previous study by Gallese investigating the mirror neuron in monkeys, one condition is the observation of a goal-oriented action. Fadiga et al. demonstrated that increasing MEP was shown when subjects observed the grasping of objects (observing movement of finger) compared with when they observed (a) the objects, (b) arm movement of the grasping objects, (c) and sham [72]. Muthukumaraswamy et al. examined whether mu rhythm modulates during observation of grasping to an object-directed [73]. The electroencephalographic mu rhythm is an 8–13-Hz rhythm generated by the sensorimotor cortex that is most prominent when subjects are resting and are attenuated or abolished when subjects move or observe biological movements [74, 75]; therefore, the hypothesis of the examination was to attenuate or abolish an 8–13-Hz rhythm during these action observations. Consistent with the hypothesis, the result showed a lower mu rhythm magnitude for the object-grip condition than for the empty-grip condition. This result is fully reasonably taken together with the studies by Fadiga and Muthukumaraswamy, which suggested that the observation of movement with intention, such as tool manipulation or daily activities, can lead to brain modulation, and as a result, these observations would be expected to be more effective for motor learning.

Another way of the effective condition was that patients imagine body movement while they observed model's action (i.e., combined action observation and motor imagery). Vogt suggested that action observation with motor imagery is more effective for motor performance than action observation therapy or motor imagery training alone [76]. Tsukazaki et al. demonstrated that the MEP amplitude was significantly increased by observing a video clip of three-ball cascade juggling combined with motor imagery of it for novel motor learning [77]. This suggested the effectiveness of action observation combined with motor imagery. By contrast, they reported that for expert subjects increased the MEP amplitude when motor imagery only (without observation). This suggested that motor imagery alone is more effective than action observation therapy combined with motor imagery for novel motor learning. As evidence of the effectiveness of action observation plus motor imagery, in neuroscience data, Taube et al. have shown that greater activation in the mirror neuron system was obtained when subjects observed the movement of others during which time subjects imagined their own body movement in terms of the model's movement [78].

In addition, previous work has been focused on observing the model's skill. According to the studies mentioned above, although the beneficial effects of action observation therapy are robust, opinions vary as to the optimal model for observers (learners). For a typical example, previous studies have shown that motor learning was promoted both with a skilled model demonstrating movement quickly without error [56, 79, 80] and with an unskilled model demonstrating slowly with error [81–83]. Taken together, the effective model's skill has not been inconsistent among the previous studies, meaning that there is no evidence for promoting a model in terms of skill for a long time. Kawasaki et al. have begun to demonstrate effective learning with action observation therapy. To date, they have conducted two investigations in young people. The results of the study were that the unskilled model demonstrating movement slowly with error was more effective than a skilled model demonstrating quickly without error [84]. Considering the clinical applications of action observation therapy, it is important to verify a model to promote for elderly persons for whom clinicians have many opportunities to care in clinical settings, because previous studies did not examine clinical settings. The ability to imagine their own body movements [35, 85] and to imitate movements after observation declines in elderly people [86]. Visual information processing of dynamic movement also declines with aging [87, 88]. Based on the previous study showing changes in body function with aging, Kawasaki and colleague investigated whether the unskilled model was effective for motor learning as the author's previous research in young people. Consistent with the hypothesis, the unskilled model showing quickness with some error has the advantage to acquire new motor skills (under review). Moreover, almost all of the subjects gained acquiring higher motor skills in subjects observed unskilled model than in subjects observed skilled model regardless of individuals' motor imagery ability; in other words, unskilled model provides observer (patients or learners) with positive effects on the motor learning with or without impairment of motor imagery ability. This suggested that motor imagery ability is not necessary when the clinicians use action observation therapy and unskilled models are readily available. In this research, positive information can be provided to apply action observation to elderly people in clinical settings.

Recently, the beneficial effects of action observation therapy have been established and applied in clinical settings. However, note that the effects of action observation therapy may be influenced by an individual's motor imagery ability. Lawrence et al. showed the effectiveness of gymnastic movement performance after observation of the movement. Additionally, the improved gymnastic movement performance in subjects having high motor imagery ability was greater than in subjects having low motor imagery ability, suggesting that the effects of action observation on motor performance are moderated by imagery ability [89]. Considering that the effects of action observation are based on imagining the individual's body movement, using the PETTPEP model would provide an advantage and lead to beneficial effects when using action observation therapy.

5. Verbalizing motor skills

To address the difficulty of motor imagery training mentioned above, verbalizing motor skills is also an effective tool for improving motor performance. Verbalizing motor skills promote to imagine own body movement because the process of verbalizing one's own motor skills would be induced by internal language [90, 91] through recalling one's own motor skills and, as a result, promoting motor imagery. The left frontal lobe is activated not only during the recalling of one's own body movement [92] but also when inducing internal language [93]. Additionally, the left frontal lobe is involved in motor programming [94]. This means that the neural circuit of verbalizing motor skill and its motor execution was shared, therefore, it is with regard to strangeness closeness relationship between verbalizing motor skill and its motor execution [95–97]. In fact, using verbal expression motor behavior leads to improved motor control and accuracy of hand grasp [98]. Considering these previous studies, we hypothesized that verbalizing of own body skills involves a process of promoting motor imagery through recalling own motor performance, as a result, the verbalizing motor skills might improve motor learning.

Based on previous knowledge, we hypothesized that the effects of verbalizing motor skills provide the subject with improved motor performance. One examination was conducted to investigate the effect of verbalizing motor skills after practicing a ball-rotation task compared with scientific read aloud (i.e., no verbalizing). The results showed the beneficial effects of verbalizing motor skills on acquiring the motor skill of finger coordination (under review, **Figure 4**). This showed that verbalizing would be effective for acquiring and improving motor skills. The author considered that verbalizing motor skills provide subjects' motor skills with beneficial effects through motor imagery. Further study is needed to analyze contents of subjects' verbalizing (qualitative research) as well as quantitative research, such as present data.

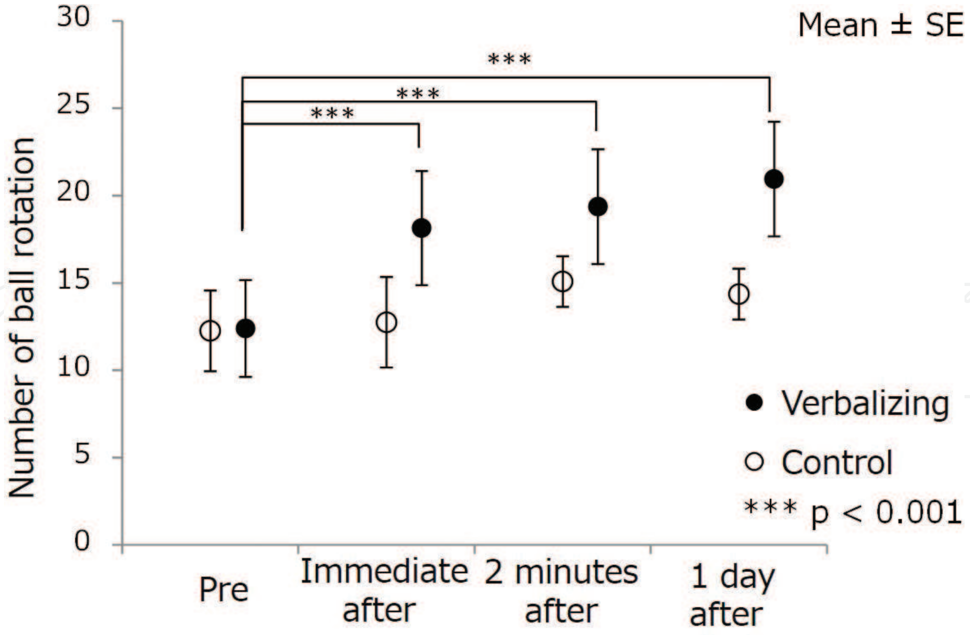

Figure 4. The changes in the number of ball rotation in all sessions. Results showed improvement of motor skills only after verbalizing.

6. Summary

There are some interventions and ideas to compensate for the shortcoming of traditional motor imagery training. This chapter studied that investigating methods of applied motor imagery training is important to develop clinical rehabilitation settings because the suggesting interventions and ideas are commonly based on motor imagery. Therefore, it is necessary to more deeply investigate motor imagery (e.g., the most effective procedure and method for individual disease characteristics), expecting that this will lead to future development of motor imagery training.

Acknowledgements

Part of this work was supported by JSPS KAKENHI Grant Number 15K16402.

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