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Original Article

An effective model for observational learning to improve novel motor performance

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Abstract. [Purpose] To investigate whether for observational learning involving a ball rotation task, an unskilled model showing clumsy finger movements is more effective than a skilled model. [Subjects and Methods] Thirty-six young adults were randomly assigned to one of three groups. The unskilled model observation group observed a video of a ball rotation task practiced by a person for a short time. The skilled model observation group observed another video of the same task practiced by the person for a relatively long time. The non-observation group did not observe any video. Regarding rotation speed, the unskilled model was faster than the participants' but slower than the skilled model. The unskilled model had the highest number of ball drops. [Results] After the observation, the unskilled model observation group showed significantly faster rotation speed than the other groups. There were no significant differences between the groups in the number of ball drops. [Conclusion] An unskilled model whose performance is better than the participants' is beneficial for improving motor performance but a model showing less skill than the participants is not.

Key words: Motor learning, Action observation, Model's skill

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INTRODUCTION

When clinicians teach patients a new motor activity in a clinical setting, they often provide an ideal demonstration of the task as a model. In most situations, the clinician expects to activate the mirror neuron system in the patient, leading the patient to imagine the body movement from a first-person perspective[1–3)], i.e., to execute the movement mentally without any movement of their body[4, 5)]. Use of such imagery has been shown to lead to the activation of the same areas of the brain as those activated by the actual movement[6–10)]. Therefore, observing actions can promote the learning of new motor skills.

Motor learning through action observation is referred to as observational learning. Observational learning has previously been reported to have beneficial effects on motor performance in younger participants. Heyes et al. reported a beneficial effect of the action observation of a sequenced tapping performance on participants' tapping[11)]. Moreover, Badets et al. showed that observational learning was effective for a motor performance in which participants needed to perform a coordination task of the upper extremities[12)]. In addition, Breslin et al. reported that observation of a bowling demonstration resulted in greater upper extremity concordance as compared with no observation[13)]. Given that these previous studies showed the benefits of observational learning in improving motor performance, action observation is expected to be useful for patients in clinical settings as a non-physically demanding tool. In particular, such an intervention may be more effective for frail elderly people because it does not present any physical demands.

However, in young participants, low brain activity in the mirror neuron system has been shown when (a) there is a difference between the model's skill and the participants' skill, and (b) the activity has not previously been experienced by the participants. Calvo-Merino et al. showed lower brain activity in novice ballet dancers than in expert ballet dancers during the observation of ballet dances[14)]. Agilit et al. reported that the cortical excitability of novice basketball players was lower than that of expert basketball players following the observation of free throws[15)]. Considering the importance of brain activity in the mirror neuron system and sensory-motor area for the improvement of motor skills[1, 16)], decreased activation in these areas following observation of a skilled model denotes ineffective motor learning.

In contrast, greater brain activity and high motor performance have been shown when characteristics of the model are similar to those of an observer. For example, infants can more easily imitate peers model than older children or adult models[17)]. In addition, the mirror neuron system of dancers was activated more strongly when they observed a video showing dancers of their own gender rather than the opposite gender[18)]. These findings indicate that models similar to the observers promote motor learning. Therefore, when partici-

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pants learn a new motor action, an unskilled model (a model who remains clumsy when performing the action) may be more effective for learning than a skilled model.

The purpose of this study was to investigate the type of model that best promotes novel motor learning. In particular, we examined whether better motor learning followed observation of a skilled model (i.e., a model able to demonstrate a complete performance) or an unskilled model (i.e., a clumsy performance, although better than the participants' naïve performance). Defining the optimal model for improving novel motor learning may be useful in clinical settings for specific types of patients, e.g., patients with serious brain damage who have to learn new motor movements such as hand actions.

SUBJECTS AND METHODS

Subjects

Thirty-six young male adults participated in this study (mean age = 21.2 years, SD = 0.8 years). All participants were strongly right- or left-handed (two participants), based on the Edinburgh handedness inventory[19]. Inclusion criteria were (a) no visual disability, (b) no previous experience of ball rotation using the hands, and (c) no previous neurological disease. All participants gave informed consent prior to participating in the study. The experimental protocols were approved by the Institutional Ethics Committee of Ryotokuji University (approval number 2622). The tenets of the Declaration of Helsinki were followed.

Methods

The participants were randomly assigned to one of three groups (unskilled model observation group [n = 11], skilled model observation group [n = 14], non-observation group [n = 11, including the two left-handed participants], Fig. 1). We ensured that there were no significant group differences in length of hand (wrist to top of the middle finger: 18.8 ± 1.1 cm; 18.1 ± 0.5 cm; and 18.2 ± 0.8 cm, respectively, for the aforementioned groups). The participants sat comfortably and were asked to perform a task involving rotating two balls in non-dominant hand to measure their baseline performance (the time required to perform 10 rotations and the number of times a ball was dropped). The balls were made from iron and were 50 mm in diameter, weighed 37 g each, and had a smooth surface. In performing the rotation task, the participants were instructed to rotate the two balls clockwise around the palm of their non-dominant hand as quickly and as smoothly as possible. They started to do the task voluntarily. We videoed their performance with a working stopwatch next to their hand; we were then able to measure the time for the 10 rotations accurately by dividing the video into frames using video conversion software (free video to JPEG converter, DVDVideoSoft Ltd., USA).

After gathering the baseline performance data, the participants in the two observation groups observed the assigned model's video for one minute, whereas the participants in the non-observation group rested, and then the participants performed the rotation task again. This was repeated for a total of three cycles, with the post-intervention performance measurements made in the same manner as for the baseline performance. We therefore collected four sets of performance data for each participant, consisting of a pre-intervention performance (labeled "pre") and three post-intervention performances (labeled "post 1," "post 2," and "post 3").

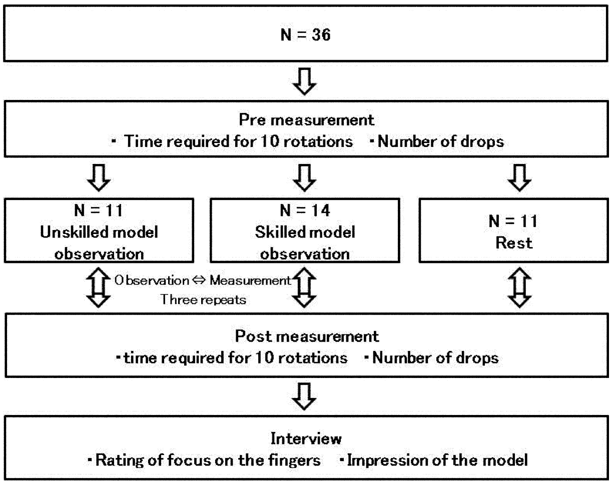

Fig. 1. Flow diagram of experiment

In the videos, the same person demonstrated the novel and expert performances. The unskilled model video showed the model performing the ball rotation task in his non-dominant (left) hand after practicing it for only 20 min. The performance was 30 seconds for 10 rotations, with balls dropped twice. The expert performance showed the ball rotation task after the model had practiced it for 10 minutes per day for 10 consecutive days. The performance was 7.5 seconds for 10 rotations with no drops of the ball from the hand. For the two left-handed participants, the video was inverted from left to right using Microsoft PowerPoint 2010.

Following this procedure, we asked the participants to rate what they focused on while watching the video, specifically the model's fingers, his palm, or the balls. With a total of 10 points to assign, the participants assigned the greatest number of points to the region they primarily focused on, and then divided the remaining points between the other two regions.

The dependent measures were rotation speed, the number of times a ball was dropped from the hand, and the participant's rating for focus on the fingers. The rotation speed was calculated by dividing each second of the video into 30 frames using the video converter software. The stopwatch was included in every frame of the video, and the calculation involved subtracting the precise time the finger movement started from the time shown on the stopwatch after exactly 10 rotations. The rotation speed and number of ball drops were analyzed using separate group (unskilled model observation group, skilled model observation group, and non-observation group) × session (pre, post 1, post 2, and post 3) analyses of variance (ANOVAs). The ratings for focus on the fingers were analyzed using a separate group (unskilled model observation group, skilled model observation group) × session (post 1, post 2, and post 3) analysis of variance (ANOVA). The level of significance was set at $p < 0.05$.

Table 1. (a) The times of required for 10 ball rotation (sec) for each observaton condition and session (Mean ± SD), (b) Number of times a ball was dropped for each observation condition and session (Mean ± SD)

	Pre	Post 1	Post 2		Post 3		
(a)							
Unskilled model	92.1 ± 86.7	42.6 ± 16.0	32.8 ± 7.7		31.1 ± 6.7		$a^{\S}$, $b^{\S}$, $c^{\S}$
Skilled model	86.7 ± 40.8	55.0 ± 20.8	51.1 ± 26.8	* †	39.9 ±12.9	* †	$a^{\S}$, $b^{\S}$, $c^{\S}$
Non-observation	82.4 ± 29.2	69.8 ± 34.3	62.4 ± 28.5		54.3 ± 22.2		$c^{\dagger}$
Mean	87.0 ± 40.6	55.7 ± 26.1	48.9 ± 25.6		41.6 ± 17.3		$a^{\S}$, $b^{\S}$, $c^{\S}$
(b)							
Unskilled model	1.18 ± 1.60	1.09 ± 1.45	0.64 ± 1.03		0.36 ± 0.92		
Skilled model	1.50 ± 2.07	1.00 ± 1.18	0.50 ± 1.09		0.64 ± 0.93		
Non-onbservation	1.82 ± 1.89	0.82 ± 0.75	0.27 ± 0.65		0.36 ± 0.67		
Mean	1.36 ± 1.84	1.04 ± 1.27	0.56 ± 1.04		0.52 ± 0.91		b^{*}, $c^{\dagger}$

Significant difference between Pre and Post 1: a, Pre and Post 2: b, Pre and Post 3: c
$^{*}p < 0.05$, $^{\dagger}p < 0.01$, $^{\S}p < 0.001$

RESULTS

The mean rotation speeds are shown in Table 1. The ANOVA showed a significant main effect of session (F (3, 99) = 31.27, p < 0.001, Table 1). There was no significant main effect of group (F (2, 33) = 2.08, ns), but there was a significant interaction between group and session (F (3, 84) = 93.86, p < 0.001). Post-hoc analysis at post 2 showed a significant difference in rotation speed between the unskilled and skilled model observation groups (t (16) = −2.42, p = 0.02), and between the unskilled model observation group and non-observation group (t (11) = −3.31, p = 0.006), but not between the skilled model observation group and non-observation group (t (23) = −1.01, ns). Post-hoc analysis of the groups at post 3 also showed a significant difference between the unskilled and skilled model observation groups (t (20) = −2.19, p = 0.03), and between the unskilled model observation group and non-observation group (t (12) = −3.31, p = 0.006), but not between the skilled model observation group and non-observation group (t (15) = −1.91, ns). In both the unskilled and skilled model observation groups, the rotation speeds in all post sessions increased significantly, although it did not do so in the non-observation group (Table 1). For the number of ball drops, there was a significant main effect of session (F (3, 69) = 3.34, p = 0.02, Table 1), but there was no significant effect of, or any interaction with group (F (1, 23) = 0.05, ns, and F (3, 69) = 0.31, ns, respectively).

For the mean of the ratings for focus on the fingers, an ANOVA showed a significant main effect of observation group (F (1, 37) = 5.70, p = 0.02). No significant main effect of session and interaction (F (2, 45) = 0.45, ns; F (2, 45= 0.45, ns, respectively). The unskilled model observation group gave higher ratings than the skilled model observation group.

DISCUSSION

The results showed that the improvement in the rotation speed (i.e., the time required for 10 rotations) was greater in the unskilled model group than in the skilled model observation group or the non-observation group. However, no differences between the groups were obtained for the number of times a ball was dropped during the task. The ratings for focus on the fingers were higher for the unskilled model observation than those for the skilled model observation.

Relative to the time required for 10 rotations in the pre-intervention baseline measurement, the time in all the post-intervention sessions in both the unskilled and skilled model observation groups became faster; this was not the case for the non-observation group. These findings indicate that model observation results in beneficial effects on motor learning. Heyes et al. and Badets et al. reported effects of model observation on motor learning in younger participants[11, 12]. Consistent with these previous reports, we showed similar effects in young participants, showing that model observation has beneficial effects on the motor learning of finger coordination.

Of particular note was the difference in the time required for 10 rotations between the unskilled model and skilled model observation groups. This suggests that post-intervention skill improvements were related to the similarity in the level of performance between the unskilled model and the participants. The importance of understanding action and movement in early phase motor learning has long been understood[20]. In fact, the rating of focus on the fingers was higher in the unskilled model observation group than in the skilled model observation group. This suggests that, by watching the finger movements of the unskilled model, the participants in the unskilled model observation group understood the task more readily than the participants in the skilled model observation group watching the finger movements of the skilled model. Taken together, these findings suggest that motor learning was promoted best in the unskilled model observation group.

Another reason for the different effects of the skilled and unskilled models on rotation speed lies in brain activity. According to previous study, during action observations, significantly greater brain activity occurs in the mirror neuron system when participants imagine their own body movement than that when participants simply observe the action[21]. This suggests that viewing a model that allows the participants to imagine their own movements is effective for observational learning. Another previous study showed significantly stronger brain activity in the mirror neuron system when the skill level between the participant and model was congruent than that when it was incongruent[14]. Considering these previous studies, the unskilled model may have activated participants' mirror neuron system, which would represent motor imagery of the finger movements involved in the ball rotation task. Consequently, motor learning would be promoted, because the skill level of participants was similar to that of the unskilled model.

There was no difference in the number of ball drops between the two model observation groups. This finding would have been affected by the two drops made by the unskilled model, which was greater than the number of ball drops made by most participants. Ikegami et al. reported that observation of a novice action model by experts in the action (i.e., experts observing poor performance) led to low performance[22]. In our study, the unskilled model dropped more balls than the participants, suggesting that the unskilled model did not lead to beneficial effects on motor performance when a model showing a lower performance was used, even though the unskilled model's skill was similar to that of the participants. Thus, certain effects of repeated ball rotation performance on motor learning were demonstrated because of natural motor learning through repetition of the ball rotation performance; these effects were not due to model observation.

In conclusion, the present study showed that observing an unskilled model had benefits in fostering ball skill performance. This advantage was shown using a model who demonstrated a higher performance level than the participants'. In clinical settings, such an unskilled model would be effective for observational learning. In particular, the unskilled model could potentially be used in clinical settings for individuals without cognitive impairment, such as fragile elderly people or patients with lower-extremity orthopedic problems. One of the limitations of the present study was that the relationship between the degree of performance improvement, the rating for focus on the fingers was fully unclear because both the rating for focus on the fingers and impressions of the model were obtained subjectively (not based on any scientific data). Another limitation was that we did not exclude the possibility that the significant improvement in the unskilled model observation group was due simply to a difference in movement speed in the video. Future studies are needed to resolve these issues and to show that using unskilled models would be an effective tool to assist with motor learning.

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REFERENCES

1) Buccino G, Riggio L: The role of the mirror neuron system in motor learning. Kinesiology, 2006, 38: 1–13.
2) Ertelt D, Small S, Solodkin A, et al.: Action observation has a positive impact on rehabilitation of motor deficits after stroke. Neuroimage, 2007, 36: T164–T173. [Medline] [CrossRef]
3) Vogt S, Di Rienzo F, Collet C, et al.: Multiple roles of motor imagery during action observation. Front Hum Neurosci, 2013, 7: 807. [Medline] [CrossRef]
4) Jeannerod M: The representing brain: neural correlates of motor intention and imagery. Behav Brain Sci, 1994, 17: 187–245. [CrossRef]
5) Mulder T: Motor imagery and action observation: cognitive tools for rehabilitation. J Neural Transm, 2007, 114: 1265–1278. [Medline] [CrossRef]
6) Ohno K, Higashi T, Sugawara K, et al.: Excitability changes in the human primary motor cortex during observation with motor imagery of chopstick use. J Phys Ther Sci, 2011, 23: 703–706. [CrossRef]
7) Ehrsson HH, Geyer S, Naito E: Imagery of voluntary movement of fingers, toes, and tongue activates corresponding body-part-specific motor representations. J Neurophysiol, 2003, 90: 3304–3316. [Medline] [CrossRef]
8) Kim J, Lee B, Lee HS, et al.: Differences in brain waves of normal persons and stroke patients during action observation and motor imagery. J Phys Ther Sci, 2014, 26: 215–218. [Medline] [CrossRef]
9) Roland PE, Larsen B, Lassen NA, et al.: Supplementary motor area and other cortical areas in organization of voluntary movements in man. J Neurophysiol, 1980, 43: 118–136. [Medline]
10) Kim JH, Chung EJ, Lee BH: A study of analysis of the brain wave with respected to action observation and motor imagery: a pilot randomized controlled trial. J Phys Ther Sci, 2013, 25: 779–782. [Medline] [CrossRef]
11) Heyes CM, Foster CL: Motor learning by observation: evidence from a serial reaction time task. Q J Exp Psychol A, 2002, 55: 593–607. [Medline] [CrossRef]
12) Badets A, Blandin Y, Shea CH: Intention in motor learning through observation. Q J Exp Psychol Hove, 2006, 59: 377–386. [Medline] [CrossRef]
13) Breslin G, Hodges NJ, Williams AM, et al.: Modelling relative motion to facilitate intra-limb coordination. Hum Mov Sci, 2005, 24: 446–463. [Medline] [CrossRef]
14) Calvo-Merino B, Glaser DE, Grèzes J, et al.: Action observation and acquired motor skills: an FMRI study with expert dancers. Cereb Cortex, 2005, 15: 1243–1249. [Medline] [CrossRef]
15) Aglioti SM, Cesari P, Romani M, et al.: Action anticipation and motor resonance in elite basketball players. Nat Neurosci, 2008, 11: 1109–1116. [Medline] [CrossRef]
16) Catmur C, Walsh V, Heyes C: Sensorimotor learning configures the human mirror system. Curr Biol, 2007, 17: 1527–1531. [Medline] [CrossRef]
17) Zmyj N, Aschersleben G, Prinz W, et al.: The peer model advantage in infants' imitation of familiar gestures performed by differently aged models. Front Psychol, 2012, 3: 252. [Medline] [CrossRef]
18) Calvo-Merino B, Grèzes J, Glaser DE, et al.: Seeing or doing? Influence of visual and motor familiarity in action observation. Curr Biol, 2006, 16: 1905–1910. [Medline] [CrossRef]
19) Oldfield RC: The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia, 1971, 9: 97–113. [Medline] [CrossRef]
20) Fitts PM: Perceptual-Motor Skill Learning. In: Categories of human learning. New York: Academic Press, 1964, pp 243–285.
21) Taube W, Mouthon M, Leukel C, et al.: Brain activity during observation and motor imagery of different balance tasks: an fMRI study. Cortex, 2015, 64: 102–114. [Medline] [CrossRef]
22) Ikegami T, Ganesh G: Watching novice action degrades expert motor performance: causation between action production and outcome prediction of observed actions by humans. Sci Rep, 2014, 4: 6989. [Medline] [CrossRef]