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Differences in Learning Facilitatory Effect of Motor Imagery and Action Observation of Golf Putting

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Abstract: The purpose of this study was to investigate differences in the learning facilitatory effect of motor imagery and action observation by analyzing the effect of these cognitive interventions on the learning of golf-putting. A total of 60 male university students were randomly assigned to 1 of 6 groups: Motor Imagery (MI), Action Observation (AO), Physical Practice (PP), Motor Imagery and Physical Practice (MI-PP), Action Observation and Physical Practice (AO-PP) and control. After a pre-test of putting performance, subjects participated in the practice program for 3 days, for 20 min a day. Subjects performed the immediate and delayed post-tests 1 day and 1 week after the practice session, respectively. For each test, variables reflecting the accuracy and consistency of putting movements were calculated and analyzed by 3-way ANOVA. In terms of the accuracy and consistency of putting results, all experimental groups, except the control group, improved significantly from the pre-test to the immediate post-test, with improvements maintained in the delayed post-test. As a result of the putting movements, the AO-PP group improved further from the immediate to the delayed post-test. These results suggest that the learning facilitatory effect of cognitive intervention can be maximized when performed together with physical practice and that physical practice with action observation is more efficient than that with motor imagery. Simultaneous performance of action observation and physical practice thus appears to be the most effective practice condition, by providing a combined learning effect, which cannot be obtained by either cognitive intervention or physical practice alone.

Key words: Motor imagery, action observation, cognitive intervention, golf-putting, physical practice, motor skills

INTRODUCTION

Motor skills in general can be learned through systematic and repeated physical practice. However, most motor skills involve both physical and cognitive factors. These facts suggest that cognitive interventions such as motor imagery and action observation can also facilitate the learning of motor skills (Magill, 2003). Motor imagery, which is an internal stimulus that induces indirect experience of the kinesthetic sense through mental representation of task performance, has been attracting much interest as a cognitive intervention method for facilitating motor learning. Motor imagery is indeed able to induce a reaction pattern similar to that generated by the neural and muscular systems during the actual performance of an imagined task. Such mechanisms can facilitate the learning of a motor skill by contributing to the development and strengthening of a proper coordination pattern of the skill to be learned (Guillot and Collect, 2005; Jeannerod and Frak, 1999; Lacourse *et al.*, 2005; Levin *et al.*, 2004; Ranganathan *et al.*, 2004; Stinear and Byblow, 2003).

However, motor imagery has some limitations in its application and such limitations can act as factors suppressing its learning effect. The effects of motor imagery can be maximized when the learner has the ability to carry out vivid and concrete imagery of the performance, as well as to control the imagery according to his intention (Weinberg and Gould, 2007). It has been shown that there are individual differences in the ability to employ motor imagery (Gregg *et al.*, 2010) and that the ability to develop the representation of task performance decreases as age increases (De Beni *et al.*, 2007). The learner's skill level can also affect imagery ability. Unlike an expert, a novice has not yet developed vivid motor representation of task performance; therefore, it is difficult to achieve a great learning facilitatory effect of motor imagery in a novice (Mulder *et al.*, 2004). Further, a common problem during the course of applying motor imagery is that there is no proper objective index for judging how much the learner is concentrating on the task and how concrete and vivid the imagery is (Papadelis *et al.*, 2007). Such limitations raise a question as to whether motor imagery is indeed a proper cognitive

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intervention for facilitating learning. It also suggests a necessity for an alternative cognitive intervention that can complement the limitations of motor imagery.

Previous research analyzing the activation pattern of brain areas and corresponding muscles involved in an actual performance of the movement by means of a model suggests that action observation can act as an alternative cognitive intervention for motor imagery (Baldissera *et al.*, 2001; Buccino *et al.*, 2001; Gangitano *et al.*, 2001; Strafella and Paus, 2000). Action observation involves observing the particular activities performed by other people or the actions of a model in a video. Like motor imagery, action observation can induce neural and muscular reaction patterns similar to those generated during the performance of an actual task and can more effectively contribute to the development of motor representations by providing concrete and vivid stimuli about the task performance (Cheng *et al.*, 2005; Fadiga *et al.*, 2005; Filimon *et al.*, 2007; Muthukumaraswamy *et al.*, 2004). This mechanism suggests that action observation can be used as a cognitive intervention method for facilitating learning. Studies have shown that action observation actually facilitates learning of diverse motor skills (Breslin *et al.*, 2005; Schoenfelder-Zohdi, 1992; Shea *et al.*, 2000; Weeks and Anderson, 2000). In a study conducted by Schoenfelder-Zohdi (1992) using the slalom ski simulator task, 1 group of participants observed the performance of a skilled model and the other group carried out the experimental task for several days upon receiving verbal instructions. The results showed that participants who had observed the skilled demonstration developed coordinated movement patterns earlier in practice than those who did not observe the demonstration.

During the process of motor learning, action observation can facilitate learning of motor skills by contributing to the promotion of the coordination pattern of the limbs or the development of a concrete and vivid motor representation of a specific effector related to the task performance. This fact suggests that action observation can be used as an alternative intervention for motor imagery. Unfortunately, the learning facilitatory effect of action observation has not attracted high interests compared to motor imagery. Therefore, in order to judge the applicability of action observation, it is necessary to investigate differences in the learning facilitatory effect of motor imagery and action observation.

Thus, the objective of the present study was to investigate differences in the learning facilitatory effect between motor imagery and action observation during golf putting. Accordingly, the hypotheses for this study were as follows: if action observation acts as a more effective cognitive intervention than motor imagery during the process of learning motor skills, then the post-test performance level will be higher in the action observation group than in the motor imagery group and the post-test performance level in the action observation group with physical practice will be higher than that in the motor imagery group with physical practice.

MATERIALS AND METHODS

Participants: This study involved 60 male university students of Keimyung University, Daegu, South Korea aged 20-26 years (average age: 23.4 years). Participants had normal or corrected-to-normal vision and were all right-handed. Prior to the experiment, all participants prepared a self-report about their task experience. They were confirmed to be beginners with no past experience in golf putting. They also read and signed a written informed consent form. The experiment was conducted from March, 2010 to July, 2010.

Experimental apparatus: The experimental apparatuses used in the present experiment included a tool for evaluating the performance of golf putting, video data for action observation and a motor imagery tool.

Tool for evaluating the performance of golf putting: An artificial putting mat was used in order to evaluate the participants' golf putting performance. A square hole with sides of 8 cm was drawn at 1, 3 and 5 m distance. In order to measure 2-dimensional performance error, with each hole as a center, score boards were installed on the putting mat. Each score board had 14 horizontal lines and 14 vertical lines drawn around the corresponding hole, with each square having an area of 5 cm^2, so that the coordinates (X-coordinate, Y-coordinate) could be accurately read for each performance. Based on the performance data, the accuracy (radial error) and consistency (variable error) of performance were determined.

Video data for action observation: The video data for action observation used in this experiment were composed of golf putting performances and verbal directions. The video data were prepared by recording the proper movements of a Semi-Pro certificated model using a high resolution digital camcorder (Sony HDR-SR7, Japan), followed by verbal directions and then editing the video according to the purpose of the experiment. The video data presented for action observation are shown in Fig. 1.

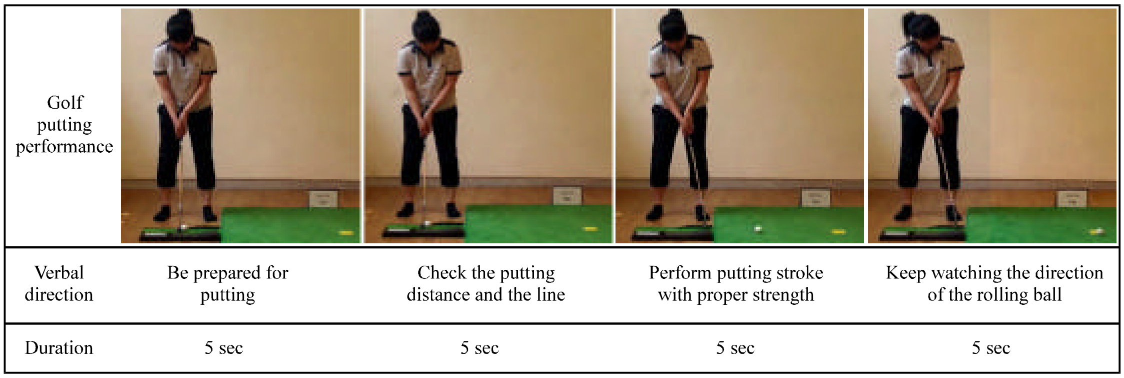

Fig. 1: The video data presented for action observation

Table 1: Practice program by group

	Practice program	
Groups	Cognitive intervention training	Physical practice
Motor imagery (n = 10)	• Imagery of task performance according to verbal instructions- a total of 60 times, 20 times from each distance (20 min duration)	• No participation in physical practice
Action observation (n = 10)	• Observation of task performance- a total of 60 times, 20 times from each distance (20 min duration)	• No participation in physical practice
Physical practice (n = 10)	• No participation in cognitive intervention training	• Performance of golf putting according to verbal instructions- a total of 60 times, 20 times from each distance (20 min duration)
Motor imagery+physical practice (n = 10)	• Imagery of task performance according to verbal instructions- a total of 30 times, 10 times from each distance (10 min duration)	• Performance of golf putting according to verbal instructions-a total of 30 times, 10 times from each distance (10 min duration)
Action observation+physical practice (n = 10)	• Observation of task performance - a total of 30 times, 10 times from each distance (10 min duration)	• Performance of golf putting according to verbal instructions - a total of 30 times, 10 times from each distance (10 min duration)
Control (n = 10)	• No participation in any activity	

Motor imagery tool: An audio system was used in this experiment as a motor imagery tool to provide verbal direction about the golf putting procedure. Using the audio system, a guided imagery experiment was conducted. The audio information for motor imagery was composed of simple verbal directions about the putting procedure, edited according to the purpose of the experiment. The content of the provided verbal direction about the putting procedure was the same as that included in the video data for action observation.

Experimental procedure

Group assignment: The 60 participants were randomly assigned to 1 of 6 groups: Motor Imagery (MI), Action Observation (AO), Physical Practice (PP), Motor Imagery with Physical Practice (MI-PP), Action Observation with Physical Practice (AO-PP) and control, with 10 participants in each group.

Pre-test: A pre-test was carried out for all participants assigned to each group 1 day before the start of the experimental treatment. A total of 10 golf putting trials were performed at a distance of 1, 3 and 5 m.

Experimental treatment by group: The experimental treatment began the day after the pre-test. The subjects received the experimental treatment for 3 days, for 20 min day^{-1}. The practice program the participants received was based on their assigned treatment group. The contents of the practice program by group are shown in Table 1.

Immediate post-test: The immediate post-test was carried out 1 day after the last practice session. During this test, the same items measured in the pre-test were recorded.

Delayed post-test: The delayed post-test was carried out 1 week after the last practice session and the same items measured in the pre-test were recorded.

Data analysis: The following variables were calculated using the data collected during the experimental procedures.

Mean radial error of putting performance: The mean radial error is a variable reflecting the 2-dimensional accuracy of performance. It can be obtained using the following equations:

$$\text{Radial Error (RE)} = \sqrt{x_i^2 + y_i^2} \quad (1)$$

$$\text{Mean RE} = (1/n)\ \Sigma\ RE_i \quad (2)$$

[x_i, y_i: coordinate values for each trial, n: total trials]

Mean variable error of putting performance: The mean variable error is a variable reflecting the 2-dimensional consistency of performance. It can be obtained using the following equations:

$$\text{Median Score } (x_c, y_c) = [(1/n)\ \Sigma x_i\ \ (1/n)\ \Sigma y_i] \quad (3)$$

$$\text{Variable Error (VE)} = \sqrt{[(x_i - x_c)^2 + (y_i - y_c)^2]} \quad (4)$$

$$\text{Mean VE} = (1/n)\ \Sigma\ VE_i \quad (5)$$

[x_i, y_i: coordinate values for each trial, n: total trials]

Data analysis: The calculated variables were analyzed by 3-way ANOVA-6 groups (MI, AO, PP, MI-PP, AO-PP and control) × 3 distances (1, 3 and 5 m) × 3 test sessions (pre-test, immediate post-test and delayed post-test) - based on repeated measurement of the last 2 factors. The significance level for all data analyses was set at 5%.

RESULTS

Accuracy of putting performance: Assessment of the accuracy of putting performance showed that the main effect of test session ($F(2,108) = 68.82$, $p<0.001$) and the main effect of distance ($F(2,108) = 1135.79$, $p<0.001$) were significant. The results of the post-hoc test on the main effects showed that the accuracy of putting performance was significantly improved in the immediate post-test compared with the pre-test and even more significantly improved in the delayed post-test compared with the immediate post-test ($p<0.001$). On the other hand, as distance increased, accuracy was found to significantly decrease ($p<0.01$). In addition, there was also a significant interaction between treatment group and test session ($F(10,108) = 3.72$, $p<0.001$), which indicates that the differences between the test sessions varied according to group (Fig. 2). The results of the post-hoc test on the differences between the sessions by group showed that, in all experimental treatment groups except the control group, there was a significant improvement in accuracy in the immediate post-test compared with the pre-test ($p<0.05$); such improvement was also maintained in the delayed post-test. For the AO-PP group, there was an even more steady improvement in accuracy in the delayed post-test compared to the immediate post-test ($p<0.01$). In contrast, the control group, which had received no treatment, showed no difference between the test sessions. There was also no statistically significant difference between groups in the pre-test.

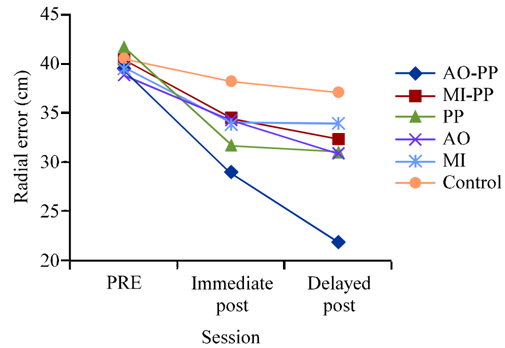

Fig. 2: Radial error of putting performance by group and session. AO-PP: Action Observation with Physical Practice; MI-PP: Motor Imagery with Physical Practice; PP: Physical Practice; AO: Action Observation; MI: Motor Imagery

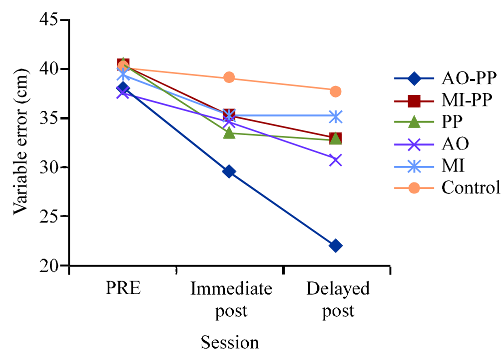

Fig. 3: Variable error of putting performance by group and session. AO-PP: Action Observation with Physical Practice; MI-PP: Motor Imagery with Physical Practice; PP: Physical Practice; AO: Action Observation; MI: Motor Imagery

Consistency of putting performance: Results of the assessment of the consistency of putting performance showed that the main effect of test session ($F(2,108) = 46.10$, $p<0.001$) and the main effect of distance ($F(2,108) = 933.55$, $p<0.001$) were significant. Furthermore, there was also a significant interaction between group and test session ($F(10,108) = 3.39$, $p<0.01$; Fig. 3). Results of the post-hoc test on the differences between the sessions by group showed that there was a significant improvement in consistency in the immediate post-test compared with the pre-test in all experimental treatment groups, except the control, AO and MI group ($p<0.01$); the improvement was also maintained in the delayed post-test. For the AO-PP group, there was an even more steady improvement in consistency in the delayed post-test compared to the immediate post-test ($p<0.01$). For the AO and MI groups, there was no significant improvement in consistency in the immediate post-test compared to the pre-test, but there was a significant improvement in the delayed post-test compared to the pre-test ($p<0.05$). In contrast, the control group showed no difference between the sessions. There was also no statistically significant difference between groups in the pre-test.

DISCUSSION

The objective of the present study was to investigate differences in the learning facilitatory effect between motor imagery and action observation during golf putting. Accordingly, the hypotheses for this study were as follows: if action observation acts as a more effective cognitive intervention than motor imagery during the process of learning motor skills, then the post-test performance level will be higher in the action observation group than in the motor imagery group and the post-test performance level in the action observation group with physical practice will be higher than that in the motor imagery group with physical practice. The results of the experiment appear to partially support these hypotheses.

Results of the analyses of the accuracy and consistency of putting performance revealed that all experimental treatment groups, except the control group, showed a significant improvement in putting accuracy and consistency in the immediate post-test compared to the pre-test. Improvement was also maintained in the delayed post-test for both accuracy and consistency. The AO-PP group also showed an even greater improvement in accuracy and consistency in the delayed post-test compared to the immediate post-test. These results imply that not only physical practice, but also cognitive interventions such as motor imagery or action observation, can facilitate the learning of a motor skill (Breslin *et al*., 2005; Hayes *et al*., 2008; Shafizadeh, 2007) and that the learning effect of these cognitive interventions can be maximized when combined with physical practice (Shea *et al*., 2000). Interestingly, the skill-learning facilitatory effect appears to be greater when physical practice is combined with action observation compared with motor imagery.

In the initial stage of motor skill learning, learners must understand and perform the standard movements required to achieve the task goal. In general, this process is carried out by means of physical practice with the explanation and feedback of an instructor. However, the standard movements required for skill performance can be perceived more easily by direct observation rather than by verbal instruction (Hecht *et al*., 2001) and the learner can obtain the necessary movement information by observing a model. In other words, action observation can contribute to the development of clear motor representation by providing vivid and concrete movement information required for skill performance, such as the spatial position of the limbs and the spatio-temporal relationship between the limbs (Breslin *et al*., 2005). In contrast, motor imagery does not provide movement information, which can suppress the learning facilitatory effect by preventing the development of motor representation.

Accordingly, the results of the putting performance assessment in this study suggest that, in novices with no experience of the task performance, action observation can be a better cognitive intervention method than motor imagery. However, although action observation provides the necessary information for the perception and organization of standard movements, it does not provide the opportunity to directly use the information related to the movements of the body segments as compared to physical practice (Hayes *et al*., 2008). In comparison, the combination of action observation and physical practice can provide a greater learning effect compared to just using one of the 2 methods (Shea *et al*., 2000; Weeks and Anderson, 2000), as we indeed showed in this study. Thus, motor learning would be more effective when using this kind of cognitive learning method.

In conclusion, the results of the present study have supported the previous research findings on the learning facilitatory effect of motor imagery and action observation. Additionally, present findings suggest that, in novices with no experience of a given task performance, action observation can act as a more effective cognitive intervention for facilitating motor learning than motor imagery and that the learning facilitatory effect of action observation can be maximized when combined with physical practice. But further studies are needed to investigate differences in learning facilitatory effect of motor imagery and action observation.

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